
GEOGRAPHICAL DISTRIBUTION
OF
WATER RESOURCES
AND
AGRICULTURAL LANDS
IN
CALIFORNIA
LEGEND
Area of Basin in Per Cent of Area of State
Agricultural Lands in Per Cent of Total of State
Water Resources in Per Cent of Total of State
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
NORTH PACIFIC BASIN
AREA 11.0 %
LAND 1.9 %
WATER 37.6 %
SACRAMENTO BASIN
AREA 16.8 %
LAND 26.8 %
WATER 34.8 %
SAN FRANCISCO BAY BASINS
AREA 2.2 %
LAND 2.6 %
WATER 1.2 %
SAN JOAQUIN BASIN
AREA 20.6 %
LAND 36.3 %
WATER 16.8 %
CENTRAL PACIFIC BASINS
AREA 7.5 %
LAND 4.1 %
WATER 3.1 %
GREAT BASIN
AREA 35.1 %
LAND 18.3 %
WATER 5.1 %
SOUTH PACIFIC BASINS
AREA 6.8 %
LAND 10.0 %
WATER 1.4 %
Eureka
Red Bluff
Chico
Lake Tahoe
Stockton
Modesto
Merced
Fresno
Visalia
Bakersfield
Needles
Yuma
San Diego
Scale of Miles
0 20 40 60 80

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

PUBLICATIONS OF THE
DIVISION OF WATER RESOURCES
EDWARD HYATT, State Engineer

Reports on State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929

BULLETIN No. 29

SAN JOAQUIN RIVER BASIN

1931

TABLE OF CONTENTS

CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER IX

CHAPTER X

LIST OF TABLES

Chapter V—Water Requirements

Chapter VI—Major Units of Ultimate State Water Plan

Chapter IX—Flood Control

LIST OF PLATES

Chapter VII—Operation and Accomplishments of Ultimate State Water Plan

Chapter VIII—Initial Development of State Water Plan

Chapter IX—Flood Control

Chapter X—Navigation

ACKNOWLEDGMENT

In the investigation of the water resources of the San Joaquin River Basin and in the preparation of a plan for their conservation, utilization and distribution, most valuable assistance and cooperation have been received.

Many individuals, irrigation districts and other public and private agencies, mutual water companies and public utilities have furnished data and information which were particularly useful in the preparation of this report.

Active and material aid in many phases of the investigation was received from departments of the Federal Government and the State.

The advice and assistance of the engineers of the Advisory Committee throughout the investigation and preparation of this report have been of inestimable value and their services are especially commended.

ORGANIZATION

Earl Lee Kelly — *Director of Public Works*
Edward Hyatt — *State Engineer*

This bulletin was prepared under the direction of

A. D. Edmonston
Deputy State Engineer

By

G. H. Jones
Associate Hydraulic Engineer

The preparatory investigational work for the bulletin was in charge of

A. L. Trowbridge
Hydraulic Engineer

Principal Assistants

C. B. Meyer — Garfield Stubblefield — P. H. Van Etten

Assistants

H. M. Crooker	G. L. Long	A. M. Wells
G. F. Mellin	E. D. Stafford	R. L. Wing
Theodore Neuman	P. E. Stephenson	J. A. Case

Delineators

J. T. Maguire — E. N. Sawtelle

Chapter IX on Flood Control was prepared by

T. B. Waddell
Hydraulic Engineer

The bulletin was edited by

Raymond Matthew
Hydraulic Engineer

J. J. Haley, Jr.
Administrative Assistant

ENGINEERING ADVISORY COMMITTEE

This investigation was outlined and the report prepared with the advice of and in consultation with the following committee of consulting engineers:

I. H. Althouse
W. H. Code
B. A. Etcheverry
F. C. Herrmann
H. L. Haehl
R. V. Meikle

SPECIAL CONSULTANTS

Consulting geologists and engineers rendered reports on special features of the investigation as follows:

Hyde Forbes, Engineer-Geologist, made geologic investigations of dam sites on the Cosumnes, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, San Joaquin, Kings, Kaweah, Tule and Kern rivers and on Dry Creek, a tributary of Mokelumne River; and also made studies of the underground reservoirs and ground water conditions in the San Joaquin Valley. His reports, entitled "Geological Reports on Dam Sites in San Joaquin River Basin," and "Geology and Underground Water Storage Capacity of San Joaquin Valley" are presented in Appendixes C and B, respectively.

Lester S. Ready, Consulting Engineer, rendered a special report on the value of electric energy that would be developed at the Friant power plant and the cost of electric energy that would be required for the operation of the San Joaquin River Pumping System.

S. T. Harding, Consulting Engineer, classified the lands on the San Joaquin Valley floor and rendered a report thereon entitled "Classification of Valley Floor Lands in San Joaquin River Basin," which is presented as Appendix A.

S. K. Love, Chemist, United States Geological Survey, analyzed samples of water of various California streams, including some in San Joaquin River Basin, and rendered a report thereon, entitled "The Chemical Character of Some Surface Waters of California," which is presented as Appendix E.

Harry Barnes, Consulting Engineer, prepared an estimate of the water requirements and rights of certain irrigated areas on the San Joaquin Valley floor. He also collaborated with Mr. Harding in the classification of the lands on the valley floor and submitted valuable data on existing conditions of irrigation development in Madera County.

C. H. Holley, Consulting Engineer, classified a part of the lands in the upper San Joaquin Valley and furnished additional information on existing conditions of irrigation development in Tulare County.

FEDERAL AGENCIES COOPERATING IN INVESTIGATION

WAR DEPARTMENT

THOMAS M. ROBINS, *Lieutenant Colonel, Corps of Engineers, Division Engineer, Pacific Division*

J. R. D. MATHESON, *Major, Corps of Engineers, District Engineer, Sacramento District of Pacific Division*

W. A. WOOD, JR., *Captain, Corps of Engineers*

Under the general direction of Colonel Robins, the general supervision of Major Matheson and the immediate direction of Captain Wood, the War Department carried out an investigation of the water resources of the Sacramento, San Joaquin and Kern rivers with a view to the formulation of general plans for the most effective improvement of navigation and the prosecution of such improvement in combination with the most efficient developments of potential water power and supplies for irrigation, and the control of floods, and rendered a report thereon. The investigation was made under authority of the River and Harbor Act of January 21, 1927, and in accordance with the provisions of House Document No. 308, 69th Congress, 1st Session. The investigations of the State and War Department were coordinated effectively without duplication of effort. The work of the War Department covered special important phases of the investigation, particularly flood control and navigation. The War Department also has furnished valuable assistance by testing the soil conditions along the San Joaquin River for determining the best location of the conveyance channel for the San Joaquin River Pumping System.

DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

ELWOOD MEAD, *Director*
R. F. WALTER, *Chief Engineer*
C. A. BISSELL, *Senior Engineer*
H. W. BASHORE, *Senior Engineer*

An investigation of the State Water Plan with particular regard to irrigation development was initiated in May, 1930, by the Bureau of Reclamation under the general direction of Dr. Mead and the immediate direction of Mr. Bissell and in cooperation with the State. The investigation was continued under the general direction of Mr. Walter and under the immediate direction of Mr. Bashore. This investigation deals principally with the formulation of a plan for the immediate relief of the improved lands with a deficient water supply in the upper San Joaquin Valley. A report on the State Water Plan and a relief project for the upper San Joaquin Valley is in course of preparation.

Geological Survey, Water Resources Branch

H. D. MCGLASHAN, *District Engineer*

Studies of the water supply of the San Joaquin River Basin were aided by the cooperation rendered by Mr. McGlashan in furnishing advance information on stream flows in the basin and in improving the installations of certain stream gaging stations maintained for this purpose. Chemical analyses of the waters of several streams of the San Joaquin River Basin also were made by this branch of the United States Geological Survey.

DEPARTMENT OF AGRICULTURE

Bureau of Public Roads, Division of Agricultural Engineering
W. W. McLaughlin, *Associate Chief*

Under cooperative agreement, the Division of Agricultural Engineering under the general direction of Mr. McLaughlin and the immediate supervision of Major O. V. P. Stout, made detailed measurements of the consumptive use of water by crops and natural vegetation in the Sacramento-San Joaquin Delta, covering a period of about six years. The Bureau in cooperation with the College of Agriculture of the University of California made a study of the cost of irrigation water in California which has been of much assistance in determining the value of irrigation supplies to be furnished under the State Water Plan. A report on this study has been published as Bulletin No. 36, Division of Water Resources. It is entitled:

"Cost of Irrigation Water in California"

by

H. F. Blaney, *Irrigation Engineer, U. S. Department of Agriculture*

and

M. R. Huberty, *Assistant Irrigation Engineer, Division of Irrigation Investigations and Practice, University of California, Agricultural Experiment Station*

Weather Bureau
E. H. Bowie, *in charge of Western States*

The Bureau cooperated in furnishing unpublished precipitation records which were of great value in the investigation.

Bureau of Chemistry and Soils
M. H. Lapham, *Inspector, District 5*

The Bureau furnished advance data on soil surveys which aided in the land classification. A. T. Strahorn of this Bureau, at the request of the Bureau of Reclamation, reviewed the State's classification of lands on the San Joaquin Valley floor.

FEDERAL POWER COMMISSION

F. E. Bonner, *Executive Secretary*
E. W. Kramer, *Regional Engineer, U. S. Forest Service, Representing the Commission in California*

In connection with the investigation of the War Department, Mr. Kramer and J. E. McCaffrey, Senior Hydroelectric Engineer, made a study of the growth of consumption of electric energy in California and the probable value of hydroelectric energy which could be generated at several units of the State Water Plan.

STATE AGENCIES COOPERATING IN INVESTIGATION

UNIVERSITY OF CALIFORNIA, COLLEGE OF AGRICULTURE

C. B. Hutchison, *Dean*

Two cooperative reports were prepared by the College of Agriculture on economic phases of the investigation, namely:

"Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley"

by

Frank Adams, *Professor of Irrigation Investigations and Practice*

and

M. R. Huberty, *Assistant Professor of Irrigation Investigations and Practice*

and

"Permissible Economic Rate of Irrigation Development in California"

by

David Weeks, *Associate Professor of Agricultural Economics*

The data in these reports published respectively as Bulletin Nos. 34 and 35, Division of Water Resources, were of particular value in determining the rate at which additional water supplies would be needed in the San Joaquin Valley and the amount that the landowners could afford to pay for these supplies.

CHAPTER 832, STATUTES OF 1929

An act making an appropriation for work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development, and utilization of the water resources of California including the Santa Ana river, Mojave river, and all water resources of southern California.

(I object to the item of $450,000.00 in section 1 and reduce the amount to $390,000.00. With this reduction I approve the bill. Dated June 17, 1929. C. C. Young, Governor.)

The people of the State of California do enact as follows:

SECTION 1. Out of any money in the state treasury not otherwise appropriated, the sum of four hundred fifty thousand dollars, or so much thereof as may be necessary, is hereby appropriated to be expended by the state department of public works in accordance with law in conducting work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana river and its tributaries, the Mojave river and its tributaries, and all other water resources of southern California.

SEC. 2. The department of public works, subject to the other provisions of this act, is empowered to expend any portion of the appropriation herein provided for the purposes of this act, in cooperation with the government of the United States of America or in cooperation with political subdivisions of the State of California; and for the purpose of such cooperation is hereby authorized to draw its claim upon said appropriation in favor of the United States of America or the appropriate agency thereof for the payment of the cost of such portion of said cooperative work as may be determined by the department of public works.

SEC. 3. Upon the sale of any bonds of this state hereafter authorized to be issued to be expended for any one or more of the purposes for which any part of the appropriation herein provided may have been expended, the amount so expended from the appropriation herein provided shall be returned into the general fund of the state treasury out of the proceeds first derived from the sale of said bonds.

FOREWORD

This report is one of a series of bulletins on the State Water Plan issued by the Division of Water Resources pursuant to Chapter 832, Statutes of 1929, directing further investigations of the water resources of California. The series includes Bulletin Nos. 25 to 36, inclusive. Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," is a summary report of the entire investigation.

Prior to the studies carried out under this act, the water resources investigation had been in progress more or less continuously since 1921 under several statutory enactments. The results of the earlier work have been published as Bulletin Nos. 3, 4, 5, 6, 9, 11, 12, 13, 14, 19 and 20 of the former Division of Engineering and Irrigation, Nos. 5, 6 and 7 of the former Division of Water Rights, and Nos. 22 and 24 of the Division of Water Resources.

The full series of water resources reports prepared under Chapter 832, twelve in number, are:

Bulletin No. 25—"Report to the Legislature of 1931 on State Water Plan."
Bulletin No. 26—"Sacramento River Basin."
Bulletin No. 27—"Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay."
Bulletin No. 28—"Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers."
Bulletin No. 29—"San Joaquin River Basin."
Bulletin No. 30—"Pacific Slope of Southern California."
Bulletin No. 31—"Santa Ana River Basin."
Bulletin No. 32—"South Coastal Basin."
Bulletin No. 33—"Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain."
Bulletin No. 34—"Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley."
Bulletin No. 35—"Permissible Economic Rate of Irrigation Development in California."
Bulletin No. 36—"Cost of Irrigation Water in California."

This bulletin presents detailed data and information on the water supplies and agricultural lands of the San Joaquin River Basin; the history and present status of irrigation, flood control, navigation and hydroelectric power developments; the utilization of water supplies from surface and underground sources; the irrigable lands and water requirements of the basin; the major units of a plan for the ultimate development and utilization of the water resources of the basin; and a proposed plan for initial development, comprising units of the ultimate plan immediately required to meet the deficiencies in water supply for present developments and needs in the San Joaquin Valley.

CHAPTER I

INTRODUCTION, SUMMARY AND CONCLUSIONS

The San Joaquin River Basin occupies that portion of California lying between the crests of the Sierra Nevada on the east, the Coast Range on the west, the San Emigdio and Tehachapi mountains on the south, and bounded on the north by the lower San Joaquin, the Mokelumne and Cosumnes rivers. It is approximately 290 miles long and 130 miles wide and embraces an area of 32,000 square miles or about one-fifth of the area of the State. In the central portion of the basin surrounded by mountainous areas lies the San Joaquin Valley, an area of 13,000 square miles of gently sloping plains with predominantly fertile soils well adapted to agriculture. The basin is drained by the San Joaquin River and its many tributaries, comprising one of the two largest stream systems within California.

The San Joaquin River Basin on the south and the Sacramento River Basin on the north together form the Great Central Basin of California, which reaches from near the northerly boundary of the State to the Tehachapi Mountains a distance of about 500 miles or nearly two-thirds the length of the State and occupies more than one-third of the State's area. The Sacramento River Basin includes in its central portion the Sacramento Valley which merges with the San Joaquin Valley on the south to form a practically continuous area of 18,000 square miles of plains designated the Great Central Valley. This northerly basin is drained by the Sacramento River and its many tributaries which comprise the largest stream system wholly within the State. The Sacramento and San Joaquin rivers flow toward each other and meet in a network of channels forming a common delta, finally combining to discharge through a common mouth into Suisun Bay and thence through San Francisco Bay into the Pacific Ocean.

The San Joaquin River Basin is devoted chiefly to agriculture. An area of about 8,500,000 acres of agricultural land or 36 per cent of the total agricultural area of the State lies in this basin. While the San Joaquin Valley in the early days of development was devoted largely to the raising of grain and cattle, the introduction of irrigation made possible the production of a great variety of crops. Irrigation development began in the decade following 1850 when diversions were made to lands lying adjacent to the streams, although areas of naturally overflowed lands had been used for pasturage prior to that time. Construction of the railroad through the valley during the period 1869 to 1875 resulted in an increase in population and a demand for suitable land for more intensive cultivation. Up to the present time more than two million acres have been placed under irrigation, more than one-third of the total area of irrigated lands in the State. The chief crops produced are deciduous and citrus fruits, olives, nuts, grapes, nearly every variety of vegetable, grain, alfalfa and cotton. Dairying and the raising of beef cattle, sheep, hogs and poultry also are important industries. It is estimated that in 1930 the value of the land, buildings, equipment and live stock utilized in the industry was about $912,917,000. The returns from crops and live stock products from the basin in 1929 amounted to $233,220,000 or about 30 per cent of the total return from these industries in the State.

Manufacturing, in the San Joaquin River Basin, is second only to agriculture as a source of income. The most important manufactured products are canned and preserved fruits and vegetables, dairy products and canned milk, lumber, lime, cement and marble. The income in the basin from the value added by manufacture, in 1929, amounted to about $68,740,000 or 5.1 per cent of the total for the entire State.

A large amount of both hydroelectric and steam-electric energy is also produced in the San Joaquin River Basin. A considerable portion of this energy is used within the basin and the remainder is transmitted to the metropolitan areas of Los Angeles and other nearby sections of southern California, and to those in the San Francisco Bay region. The power plants of the basin have an installed capacity of about 911,000 kilovolt amperes and in 1929 produced about 3,240,000,000 kilowatt hours of electric energy or about 37 per cent of the total production in the State.

Mineral production ranks third in source of income. The value of all mineral products from the San Joaquin River Basin in 1929 amounted to $54,730,000 or 12.7 per cent of the total for the entire State. This included $37,375,000 for petroleum, $3,015,000 for natural gas, $2,340,000 for gold and $12,000,000 for miscellaneous minerals. The latter item includes, silver, copper, lead, quicksilver, tungsten, gems, platinum, barytes, coal, manganese, chromite, gypsum, marble, magnesite, dolomite, silica, pumice, clay for pottery and bricks, slate, limestone, granite, borates, assorted building stone, volcanic ash, salt, diatomaceous earth, minerals for paint, lime and other materials for the manufacture of cement, and mineral water.

The present population of the San Joaquin River Basin is about 575,000, more than one-tenth of that of the entire State. It can be classed as about 40 per cent urban and 60 per cent rural. Over 95 per cent of the population resides in the San Joaquin Valley. During the last decade, the population increased about 28 per cent while during the previous decade it increased over 60 per cent. The largest cities in the basin are Fresno and Stockton, the industrial and commercial centers of the San Joaquin Valley and its environs. The former city has a population of 53,000 and the latter 48,000. The completion of the Stockton Deep Water Channel to San Francisco Bay in the near future will make this city a port of call for ocean-going vessels. Bakersfield and Modesto are the next important cities. The former has a population of 26,000 and the latter 14,000. Other incorporated cities and towns having a population of more than 2500 in order of size are: Visalia, 7300; Merced, 7100; Hanford, 7000; Lodi, 6800; Tulare, 6200; Porterville, 5300; Madera, 4700; Turlock, 4300; Lindsay, 3900; Tracy, 3800; Taft, 3400; Selma, 3000; Sanger, 3000; Dinuba, 3000; Coalinga, 2900; Exeter, 2700; Delano, 2600 and Reedley, 2600.

The basin, especially the San Joaquin Valley, is well served by transportation facilities. It is traversed from north to south by the

Southern Pacific Railroad, which has two main lines from Fresno north and one main line from Fresno south, and by the main line of the Santa Fe Railroad. There are also numerous branches from the main line railroads into the mountains and different parts of the valley. Electric lines connect urban areas in certain sections of the valley. A network of improved highways throughout practically the entire basin also provides facilities for rapid motor truck transportation, either for short or long hauls, and such transportation is now competitive with that by rail.

Water Problems in San Joaquin River Basin.

Irrigation development has been so rapid and extensive in the San Joaquin Valley that local water supplies are now insufficient to meet the needs of present irrigated areas, particularly in the southern or upper portion of the valley south of the Chowchilla River. On all of the streams tributary to the upper San Joaquin Valley, there long since has been effected a very high degree of utilization of run-off without surface storage regulation. For many years, while the irrigated areas devoted to annuals have varied from season to season with the available amount of surface water supplies, the expansion of irrigated areas devoted to permanent crops has occurred chiefly through the development of ground water supplies. With limited or no surface supplies, the replenishment of ground water storage, commonly resulting from the use of ample surface irrigation applications, is lacking in many of these areas. In some localities, expansion of irrigated areas has continued to such an extent that the net draft on ground water storage exceeds the average seasonal replenishment from whatever local sources are available. The result has been a depletion in ground water storage, which is indicated by a continuously receding water table. Out of a total irrigated area in the upper San Joaquin Valley of 1,200,000 acres drawing their supplies both from streams and wells, some 400,000 acres are now overdrawing the water supplies naturally available to them. Studies reveal that there is only about one- half the amount of water for their full requirements. With the recession of ground water levels, water supplies in some areas have become exhausted while in others pumping lifts have become so excessive as to be economically prohibitive. Farms and homes have already been abandoned for the lack of an adequate and dependable water supply. It appears probable that some 200,000 acres must go back to desert condition if a supplemental water supply is not obtained in the near future. These 200,000 acres are valued at more than $50,000,000 and yield annually under normal economic conditions $20,000,000 worth of agricultural products.

In the Sacramento-San Joaquin Delta, about two-thirds of which lies in the San Joaquin River Basin, the available inflow from the Sacramento and San Joaquin River systems during recent years of generally subnormal run-off has been insufficient during certain months of several years to meet the consumptive demands in the delta and adjacent delta uplands drawing their supplies from the delta channels, and to keep the water fresh against invasion of saline water from San Francisco Bay. Saline invasion has rendered the water unfit for irrigation and other uses, not only in the delta and adjacent delta uplands but also in the adjacent upper San Francisco Bay Basin in the area adjoining Suisun Bay. The resulting curtailment of irrigation in the delta has caused material losses in crop production which in 1931 is estimated to have been about $1,300,000. In addition, the salinity menace with a possibility of more extensive and prolonged invasion in future years than has occurred in the past has tended to depreciate land values in this most fertile and productive region. Moreover, industries and agricultural lands in the areas adjacent to Suisun Bay have been curtailed in their use of fresh water from the lower river and upper bay channels with losses resulting of substantial amount. Additional water supplies are urgently needed to prevent saline invasion into the delta channels and maintain continuous fresh water therein, and to provide for the full consumptive needs of the delta and adjacent upland areas and for the nearby industrial and agricultural areas in the upper San Francisco Bay region.

In addition to the problems of water shortage in the San Joaquin River Basin, there are problems of flood control and navigation which should receive attention. Disastrous floods have occurred in past years of large run-off and the possibility of their repetition is a menace to some of the improved valley lands and populated areas. Although works for flood protection have been provided for considerable portions of the areas subject to flood menace, there is a need for additional flood protection on many of the streams in the basin. The problem of navigation involves chiefly the upper San Joaquin River above Stockton. This waterway from Stockton to Mendota is potentially navigable and in former years was actually navigated by commercial craft operating as far upstream as Mendota and occasionally to Herndon. Because of deficient stream flow during several months of the year resulting in inadequate navigation depths, transportation by water has never been dependable on this stream. This waterway is worthy of improvement from Stockton to Mendota to provide cheap water transportation for the large volume of tonnage moving to and from the San Joaquin Valley.

Studies reveal that, even with a full practicable development of the water resources of the San Joaquin River Basin, additional water supplies will be needed to meet the full requirements in the basin. On the other hand, the water supplies in the Sacramento River Basin are in excess of its full requirements. The most logical and practical source of supplemental water supply for the San Joaquin River Basin is the surplus water which could be made available in the Sacramento River Basin. The adequate solution of the water problems of the San Joaquin River Basin, therefore, involves plans for development of water supplies not only in its own basin but also in the Sacramento River Basin.

A proper and coordinate solution of the water problems of the San Joaquin River Basin is highly desirable. The investigations upon which this report is based have been directed to this purpose together with the formulation of a general plan for the conservation, regulation, distribution and utilization of the water resources to provide for the ultimate needs of the basin.

Previous Investigations.

Investigations of the water resources of the Great Central Basin with a view of utilizing the water for the greatest beneficial uses have been made at various times over a long period of years. Some of the more important of these are enumerated in the following paragraphs.

In 1873 an investigation was made by the United States War Department and a plan was outlined for utilizing the water supply to the greatest advantage for irrigation purposes.

The first effort of the State to make an investigation of its water resources and offer a solution of the problem concerning water utilization was made in 1878 and resulted in "An act to provide a system of irrigation, promote rapid drainage and improve navigation on the Sacramento and San Joaquin rivers." Under this act, investigations were carried out by the State Engineer, William Ham. Hall. He, like the Army Engineers in 1873, suggested that the water of the Great Central Valley be developed in a systematic manner. Several reports and maps were published by the State Engineer between 1880 and 1888.

In 1900, the United States Department of Agriculture, Office of Experiment Stations, made an investigation of irrigation conditions and recommended certain changes in the water laws of the State.

In 1906, a report on hydrographic investigations in the Sacramento Basin, California, was prepared by S. G. Bennett, engineer for the United States Reclamation Service. This report summarized data on irrigation and reclamation from other reports and described a number of reservoir sites and possible storage and irrigation projects in the basin.

Another State investigation was made in 1911 through a special board called the "Conservation Commission," which issued a report on its findings.

In 1912, the United States Department of Agriculture made an investigation and issued a bulletin dealing with the irrigation resources and their development.

The State investigations known as "The California Water Resources Investigations" were initiated in 1921. These investigations have been carried on under the direction of the State Engineer in accord with successive authorizations of the Legislature in 1921, 1925, 1927 and 1929.

Scope of Present Investigation.

The present investigation has been directed to the formulation of plans for the ultimate conservation, regulation, distribution and utilization of the water resources of the San Joaquin River Basin for all necessary and desirable purposes and, of more immediate importance, to the solution of the present water problems in the basin involving the determination of a plan for initial development comprising units of the ultimate plan required to meet the immediate needs. Because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for supplemental waters to meet its full requirements, the plans for both initial and ultimate development in the two basins are interrelated and interdependent and, therefore, have been considered together as one unified project for the entire Great Central Valley.

In the formulation of the State Water Plan in the Great Central Valley, studies in addition to those presented in this report on the San Joaquin River Basin have been made covering the Sacramento River Basin, the Sacramento-San Joaquin Delta and upper San Francisco Bay Basin, including an investigation of the feasibility of constructing a barrier at some point below the confluence of the Sacramento and San Joaquin rivers to prevent invasion of saline water into the delta. The results of these investigations are presented in other reports.*

This bulletin presents the detailed data and studies of the water resources investigations for the State Water Plan in the San Joaquin River Basin. It sets forth the available water supply, the area, location and quality of agricultural lands, the history and present status of irrigation, flood control, navigation and hydroelectric power developments, the utilization of surface and ground water supplies, an estimate of the area of lands suitable for irrigation, the present and ultimate water requirements for all purposes, the major units of an engineering plan for the ultimate development, regulation and utilization of the water resources of the basin, and a plan for initial development comprising units of the ultimate plan immediately required to meet the deficiencies in water supply for present developments and needs in the San Joaquin Valley.

In the studies of water supply, estimates were made of the run-off at various points for the 40-year period 1889–1929. These estimates were based on records of precipitation in the basin for the entire period and on stream flow measurements which were started as early as 1893 and which are available for about 20 years on streams contributing approximately 90 per cent of the run-off from mountain areas. Estimates of full natural run-off were made for all of the major streams and groups of minor streams. Full natural run-offs and those under present and ultimate conditions of development, at the dam sites of the major reservoir units in the San Joaquin River Basin, also were estimated. Studies also were made of the distribution of the run-off and the occurrence and distribution of return waters and ground water. The present and ultimate net run-offs, estimated for the 40-year period 1889–1929,** were used in the reservoir studies to determine the required storage capacities, and to estimate the amounts of utilizable water supply obtainable through the operation of surface storage reservoirs, underground storage and pumping and conveyance units as proposed.

---

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.
Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.
Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

** Since the preparation of the water supply studies in this report based upon the run-offs for the 40-year period 1889–1929, on which the major units of the State Water Plan for initial and ultimate developments were proportioned and on which the utilizable water supply obtainable from each plan of development was determined to test its adequacy in meeting the requirements, two seasons of low run-off have occurred, 1929–30 and 1930–31. Therefore, it was deemed desirable to test the adequacy of the plans proposed for initial and ultimate development of the San Joaquin River Basin by the inclusion of these seasons in the water supply analyses, and if either plan were found inadequate, to point out wherein, if possible, a modification of it could be made which would assure dependable supplies to all areas served by the plan. The results of the supplemental analyses of water supply through the season 1930–31, which, with minor changes in the plan of operation, show that the proposed plans for both initial and ultimate developments would be adequate to meet the requirements, are presented in Appendix D.

A classification was made in the field of all agricultural lands in the San Joaquin Valley and adjacent foothills on the basis of their adaptability for irrigation, utilizing soil surveys, where available, as a guide. This classification covered an area of about nine million acres. A survey also was made of the crops now grown on the lands of various classes to obtain data on the areas and locations of the different kinds of crops both irrigated and nonirrigated, and to determine the adaptability of different localities and classes of land to the growing of different types of crops. Data also were obtained on the net water requirements for these irrigated lands and incidental information on conveyance losses and gross requirements. Based upon these data, the ultimate water requirements in the areas to be served were estimated for the mountain and foothill lands above the major reservoir units, and for the valley floor lands, by divisions or zones of service as related to source of supply including local streams and imported water from outside the basin. Estimates were made of the gross allowance or diversion, the net allowance or water delivered to the land, and the net use of water or the amount from which no return would be available.

An engineering plan for the ultimate development of all of the lands considered feasible of development was evolved. The location and extent of the developed lands now under irrigation and in need of a supplemental water supply were determined and the amount of the required supplemental supply estimated. An initial plan of development for furnishing a supplemental water supply to the developed lands in need of additional water was evolved, which would constitute the first progressive step in the plan for ultimate development.

Analyses were made of all phases of the coordinated operation of the major units of the State Water Plan in the Great Central Basin in accord with the plans for both initial and ultimate development, in order to test the adequacy of each plan in meeting the requirements and effecting all objectives sought and desired.

In the formulation of plans for storage and conveyance of water supplies, many studies were made to determine the best location for, and the most economic size of, each unit, and the most practicable plan of coordinated operation to meet the requirements for irrigation, salinity control, flood control, power development and navigation. Analyses were made of reservoirs at various sites on each major stream to determine the most feasible location and the economic capacity for the purposes to be served. Topographic surveys were made of all reservoirs and dam sites for which maps were not available. Field examinations of reservoir sites were made to appraise the values of lands and improvements which would be submerged and these values were checked by comparison with data from county assessors and other sources. Some of the dam sites were explored by shafts, tunnels and core drillings, and geologic studies by competent geologists were made of all sites. From these geologic data, estimates were made of the depths of excavation necessary to obtain satisfactory foundations for the dams. The economic installations of power plants at the dams of the major reservoirs also were carefully considered. Due to the importance of the utilization of underground reservoirs in the San

Joaquin Valley, a geologic study was made to locate underground storage areas, to estimate their capacity and determine the practicability of their utilization for the storage and extraction of water supplies. Detailed studies were made of the operation of underground reservoirs in combination with surface storage regulation. Many alternate plans were investigated for the conveyance from the Sacramento River of the water required to supplement the available local supplies in the San Joaquin River Basin, and the distribution and utilization of such imported supplies in coordination with local supplies in the basin. These investigations necessitated the making of numerous topographic and location surveys, explorations, and field examinations for valuation of right of ways.

Data also were obtained on unit costs of materials and all parts of the construction work and on the probable length of time required for construction. With these data and the estimated quantities involved in different parts of the construction, estimates were made of the costs of the dams, reservoirs, power plants and conduits. Data also were obtained on the costs of operation, maintenance and depreciation of the different features of the units and with these data and assumed interest and amortization charges, estimates were made of annual costs.

In the following chapters of this report, there are presented in detail the basic studies and investigations and the proposed plans of development and operation for the State Water Plan in the San Joaquin River Basin. These are briefly summarized with conclusions in the remaining portion of this chapter.

Water Supply.

Precipitation—The precipitation in the San Joaquin River Basin is extremely variable both geographically and seasonally. It ranges in seasonal average from 50 inches in the mountains to less than 10 inches on the valley floor and varies in different seasons and localities from a minimum of 25 to a maximum of 192 per cent of the mean. It occurs in the form of snow in the high mountains, which melts in the spring and early summer months to produce a large percentage of the run-off. On the average, about 90 per cent of the precipitation falls during the months of November to April inclusive, with little or no rainfall in the valley during the growing season when the moisture demands of crops are at their peak.

Run-off—The San Joaquin River Basin, while occupying 20.6 per cent of the total area of California, yields from its mountainous portion only 16.8 per cent of the total water supply from the entire mountainous area of the State. The basin is drained by the San Joaquin River and its numerous tributaries, comprising 13 major streams and 22 minor streams or stream groups. The following tabulation shows the areas of the drainage basins and the mean seasonal full natural run-offs from the mountain and foothill areas for each stream and stream group, with subtotals for the upper San Joaquin Basin, the lower San Joaquin Basin (south of the delta), and the tributaries discharging directly into the delta. The streams of the upper San Joaquin Basin include the Chowchilla River and all those to the south of that stream. The streams of the lower San Joaquin Basin include all those south of the delta from the Chowchilla River north to and including the Stanislaus River. The delta tributary streams include those north of the Stanislaus River to and including the Cosumnes River. The contributions to the surface run-off and possible ground water replenishment, from rainfall on the valley floor, are not included because of the lack of definite knowledge as to their amounts.

FULL NATURAL RUN-OFF OF SAN JOAQUIN RIVER BASIN STREAMS

Stream or stream group	Drainage area, in square miles	Seasonal full natural run-off, in acre-feet (Season October 1 to September 30)			
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929
Upper San Joaquin Basin—					
Panoche Creek	295	26,400	24,200	14,000	13,200
Cantua Creek group	208	12,600	11,300	6,100	5,500
Los Gatos Creek	119	9,400	8,400	4,800	4,300
Tejon Creek group	1,341	88,600	74,700	43,900	41,000
Caliente Creek	471	37,300	28,900	21,900	22,100
Kern River	2,410	725,000	691,000	505,000	466,000
Poso Creek group	576	45,500	38,600	32,300	35,300
Deer Creek	110	19,500	16,500	13,400	12,600
Tule River	390	135,000	113,000	87,200	77,600
Yokohl Creek group	98	14,200	12,000	10,000	10,900
Kaweah River	514	443,000	355,000	311,000	291,000
Lime Kiln Creek group	201	60,600	52,900	46,000	49,700
Kings River	1,694	1,889,000	1,580,000	1,321,000	1,226,000
Dry Creek	48	4,100	3,600	3,000	2,600
San Joaquin River	1,631	1,995,000	1,699,000	1,405,000	1,333,000
Cottonwood Creek	28	2,100	1,800	1,400	1,200
Fresno River	270	63,400	56,300	46,300	38,900
Daulton Creek group	66	4,600	3,900	3,200	2,700
Chowchilla River	238	70,900	56,200	56,900	55,100
Totals, Upper San Joaquin Basin	10,708	5,646,200	4,827,300	3,932,400	3,688,700
Lower San Joaquin Basin—					
Orestimba Creek group	1,340	120,000	102,000	87,200	78,600
Dutchman Creek group	72	8,600	6,000	5,700	5,900
Mariposa Creek	103	13,200	9,400	9,000	9,100
Owens Creek group	66	6,700	4,500	4,300	4,400
Bear Creek	71	7,800	5,300	5,100	5,200
Burns Creek group	171	25,400	18,700	18,300	18,800
Merced River	1,054	1,115,000	944,000	814,000	765,000
Tuolumne River	1,543	2,070,000	1,772,000	1,577,000	1,520,000
Wildcat Creek group	59	9,200	6,500	6,300	6,500
Stanislaus River	983	1,350,000	1,108,000	949,000	932,000
Totals, Lower San Joaquin Basin	5,462	4,725,900	3,976,400	3,475,900	3,345,500
Delta Tributaries—					
Littlejohns Creek	41	8,400	6,200	6,000	6,200
Martells Creek group	122	14,900	11,100	10,700	11,100
Calaveras River	394	227,000	191,000	131,000	115,000
Mokelumne River	632	853,000	726,000	626,000	618,000
Sutter Creek group	285	97,600	75,600	75,900	70,500
Cosumnes River	534	407,000	346,000	289,000	282,000
Totals, Delta Tributaries	2,008	1,607,900	1,355,900	1,138,600	1,102,800
Grand totals	18,178	11,980,000	10,159,600	8,546,900	8,137,000

All of the full natural run-off of most of the streams, at the sites for the major reservoir units of the State Water Plan, is not now available, and in the future probably even less will be available, for conservation by the reservoirs. The "present net run-offs" at any point are those which would occur under present conditions of development in the tributary basin. The "ultimate net run-offs" are those which would occur with ultimate instead of present conditions of development in the tributary drainage basin. These present and ultimate net run-offs were used in studies of water supply yield under present and ultimate conditions respectively. The mean seasonal net run-off from the San Joaquin River Basin into San Joaquin Delta for the 12-year period 1917–1929, under conditions of irrigation and storage development as of 1929 and municipal diversions out of the basin as of 1940, is set forth in the first of the following tabulations. The second tabulation sets forth the mean seasonal ultimate net run-off of each of the major streams at the reservoir sites considered in the ultimate State Water Plan, and the area of the drainage basin above each reservoir.

PRESENT NET RUN-OFF INTO SAN JOAQUIN DELTA

Mean for 12-Year Period 1917-1929

Stream	Present seasonal net run-off, in acre-feet (Season October 1 to September 30)
San Joaquin River at Newman	1,180,100
Tuolumne River at confluence with San Joaquin River	1,045,000
Stanislaus River at confluence with San Joaquin River	665,000
Calaveras River at Jenny Lind	135,000
Mokelumne River below Woodbridge	510,000
Dry Creek near Ione	64,800
Cosumnes River below Michigan Bar	269,000
Total	3,868,900
Pumping diversions below gaging stations	89,300
Net run-off into San Joaquin Delta	3,779,600

ULTIMATE NET RUN-OFF OF MAJOR STREAMS IN SAN JOAQUIN RIVER BASIN

Stream	Drainage area, in square miles	Ultimate seasonal net run-off, in acre-feet (Season October 1 to September 30)			
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929
Kern River	2,080	714,000	679,000	493,000	454,000
Tule River*	338	130,000	109,000	84,100	74,500
Kaweah River	514	443,000	355,000	311,000	291,000
Kings River	1,544	1,889,000	1,580,000	1,321,000	1,226,000
San Joaquin River	1,631	1,993,000	1,702,000	1,398,000	1,300,000
Fresno River	102	55,200	48,200	39,800	34,000
Chowchilla River	238	70,900	56,200	56,900	55,100
Merced River	1,034	989,000	825,000	705,000	659,000
Tuolumne River	1,536	1,634,000	1,393,000	1,240,000	1,230,000
Stanislaus River	900	1,239,000	997,000	839,000	820,000
Calaveras River	363	189,000	156,000	96,400	80,100
Mokelumne River	575	820,000	696,000	597,000	581,000
Cosumnes River	435	290,000	235,000	182,000	169,000
Totals	11,290	10,456,100	8,831,400	7,363,200	6,973,700

*Includes South Fork of Tule River, which enters the main Tule below the reservoir site of the State Water Plan.

There are wide variations in seasonal, monthly and daily run-off. The data on natural flow for the period 1889–1929 show that the seasonal run-off varies on different streams from maximums of 225 to 357 per cent to minimums of 10 to 28 per cent of the 40-year mean; and that, on most of the major streams, 75 to 80 per cent of the total seasonal run-off occurs on the average during about five months of the spring and early summer. Daily variations in flow range from practically nothing to several thousand second-feet.

Return Water—In the San Joaquin River Basin a substantial potential water supply is that from water which, once used for irrigation, domestic or other purposes, would return to the streams or accumulate in the various ground water basins. The return waters from irrigation would have their sources in the losses from canals or other conduits during conveyance of water from the points of diversion on the streams to points of use and in irrigation applications in excess of consumptive use. A large portion of the return waters from the mountain and foothill region would be available for storage in the major reservoir units of the State Water Plan in which they could be regulated to a supply conforming to the irrigation demand on the valley floor. In the upper San Joaquin Valley, which is that portion southward from Mendota and the Chowchilla River, most of the waters diverted to the valley floor in excess of consumptive use would be utilized by pumping from underground reservoirs. The efficient utilization of these ground water reservoirs would allow only a relatively small portion of this water to reach the valley trough channels. In the lower San Joaquin Valley, northward from Mendota and the Chowchilla River, the waters diverted to the valley floor in excess of consumptive use would enter the streams or artificial drains and finally reach the San Joaquin River or would replenish the underground basins. The return waters reaching the San Joaquin River could be made available for reuse on adjacent lands or exportation to other areas through the major conveyance units of the State Water Plan.

Agricultural Lands.

The agricultural lands in the San Joaquin River Basin comprise about 36.3 per cent of those in the entire State. The classification of agricultural lands on the basis of their adaptability for crop production and irrigation, made during the present investigation, covered all those lands lying in the San Joaquin Valley and adjacent foothills.

The lands were divided into five classes, the first four of which are considered as agricultural and the fifth as having no present or potential agricultural value. The character of the soil and topographic and surface features determined the class in which each parcel of land was placed. A certain percentage of each class of agricultural land was estimated to be capable of irrigation and these percentages applied to the areas of the respective classes of land in any tract, gave the irrigable area of that tract. The gross agricultural and net irrigable areas in the basin, estimated during this investigation, are shown in the following tabulation:

AREAS OF AGRICULTURAL AND IRRIGABLE LANDS IN SAN JOAQUIN RIVER BASIN

Section	Gross agricultural area		Net irrigable area	
	In acres	In per cent of total	In acres	In per cent of total
Upper San Joaquin Valley floor	4,881,800	57.4	3,648,000	61.2
Lower San Joaquin Valley floor	2,360,600	27.8	1,676,000	28.1
Foothill areas	977,000	11.5	380,000	6.4
San Joaquin Delta	279,000	3.3	257,000	4.3
Totals	8,498,400	100.0	5,961,000	100.0

Irrigation Development and Water Supply Utilization.

Favorable soil and climatic conditions, with the one exception of adequacy of rainfall, have made the San Joaquin Valley a pioner section in the irrigation development of California. Starting in the decade following 1850, the early irrigation enterprises were largely undertaken by individuals. Subsequently, larger enterprises were undertaken under various forms of organization including first, private and mutual water companies and later irrigation district and other similar forms of organization.

There are now 36 active irrigation districts embracing a gross area of 1,826,578 acres of which 1,143,840 acres were irrigated in 1929; 16 public utility water companies irrigating approximately 184,000 acres in 1929; and 48 mutual water companies irrigating in 1929 approximately 336,000 acres. There are also several water storage, conservation, reclamation and other forms of public district organization under which lands are irrigated in the San Joaquin Valley.

Irrigation development has been rapid and extensive, particularly in the last three decades. The area irrigated has increased from about 800,000 acres in 1900 to about two and one-quarter million acres in 1929, which comprises more than one-third of the irrigated land in the State and about two-fifths of the entire net acreage susceptible of irrigation in the San Joaquin River Basin. The following tabulation sets forth the areas of irrigated crops in the San Joaquin River Basin in 1929.

IRRIGATED CROPS IN THE SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS—1929

Portion of basin	Area of irrigated crops, in acres											
	Citrus orchards	Deciduous orchards, including figs, nuts and olives	Grape vineyards	Grain	Alfalfa	Field crops	Cotton	Irrigated pasture land	Truck crops	Rice	Unclassified	Totals
Upper San Joaquin Valley	41,600	122,600	349,700	64,300	174,200	123,000	212,500	62,900	6,500	1,000	43,500	1,201,800
Lower San Joaquin Valley and adjacent foothills	200	107,500	116,000	131,200	211,600	31,500	66,400	61,500	84,200	15,600	6,100	831,800
Totals, excluding delta	41,800	230,100	465,700	195,500	385,800	154,500	278,900	124,400	90,700	16,600	49,600	2,033,600
San Joaquin Delta,[1] in Contra Costa and San Joaquin counties	0	1,500	0	66,100	16,100	34,000	0	10,800	65,800	0	0	194,300
Totals	41,800	231,600	465,700	261,600	401,900	188,500	278,900	135,200	156,500	16,600	49,600	2,227,900

[1] The San Joaquin Delta also includes 24,500 acres of crops irrigated in 1929 in Sacramento County.

Irrigated crops comprise 79 per cent of all crops produced in the San Joaquin River Basin in 1929. Of the unirrigated crops, grain constitutes 97 per cent of the total acreage.

The early enterprises made use of the natural stream flow only. Due to the rapid reduction in stream flow following the melting of snow on the higher drainage areas, usually in June or early July, the lands which could be given full service without storage were limited. Many areas received only a partial service and either adjusted the crops to those of early maturity, or by excessive use of flood waters, while available, raised the ground water to provide at least partial subirrigation during the remainder of the season. Waterlogging was caused in many instances by such excessive applications, and continued high ground water resulted in soil injury through alkali accumulations in many areas.

In the southern or upper valley, the first irrigation developments were made by direct surface diversion to the lands, principally on the delta fans. For areas distant from streams, where surface supplies were not obtainable, ground water was found to be available and pumping began to be practiced in the early part of the present century. In many localities, where artesian wells first were secured, increased draft has resulted in a lowering of water levels and pumping is now required. Pumping from wells has been developed to a very large extent in this section of the valley, where stream flow is small in relation to the demand. On the Kings and Kaweah river deltas, pumping from wells, within the irrigated areas, is extensively used to supplement direct surface diversion. For areas further south, practice includes all variations from entire dependence on stream diversion to full pumping or combinations of these two practices.

Due to the low run-off of the 1928–1929 season, the irrigated areas for the upper San Joaquin Valley are somewhat below the average. None of the streams, tributary to this portion of the basin, are regulated by surface irrigation storage and the limit of utilization of their surface run-off under existing diversion rights has long since been reached. The cropped land, irrigated solely from surface diversion, varies through wet and dry periods. This is particularly true where lands are in large holdings. On the other hand, the extent of irrigated areas, entirely dependent upon a supply pumped from ground water, has been increasing rapidly even though the water levels underlying these areas have been receding steadily. It is estimated that the acreage so served, in 1929, is the maximum of record.

As a result of the increase in use of ground water supplies in the upper San Joaquin Valley during the period of generally subnormal run-off extending over the past decade or more, ground water levels have been depressed in the most of the irrigated areas of the upper San Joaquin Valley. In some areas lacking adequate sources of ground water replenishment, underground supplies either have become exhausted or ground water levels have dropped to such an extent that pumping lifts are now excessive. During the period 1921–1929 the lowering in areas of heavy pumping draft has varied generally from 25 to 50 feet where no direct sources of supply were available, with maximum lowering in one area of 85 feet. In the major portions of areas having direct sources of water supply such as the Kings and

Kaweah river deltas, a lowering from 5 to 10 feet has occurred. From the known extent of recession, it is estimated that the average seasonal depletion of ground water, in an area of about 400,000 acres in which the available supply even over a long period is insufficient to support present requirements, has amounted to 387,000 acre-feet over the 8-year period 1921–1929. Based upon records of ground water fluctuation, irrigated areas, and estimates of net inflow to the underground basins, the present net use requirements of the several absorptive areas of the upper San Joaquin Valley were found to average about 2 acre-feet per acre of area irrigated.

In the northern or lower valley, direct surface diversions were used until the developments had become sufficiently extensive to enable storage to be financed. These storage developments were made, to a large extent, economically feasible by the development and sale of hydroelectric energy in conjunction with the storage and release of irrigation water. Such storage is now in use on the Merced, Tuolumne and Stanislaus rivers. Pumping from wells is limited to drainage. However, drainage water, in most instances, is reused for irrigation. On the San Joaquin River, some storage for power is now available as a partial aid to irrigation. Supplies from the lower portions of the San Joaquin River have been obtained by pumping rather than by gravity diversion. A large area above the mouth of Merced River, including about 309,000 acres of land devoted to crops, is irrigated from the main San Joaquin River with diversion works at or near Mendota. Lands irrigated by the Merced, Tuolumne and Stanislaus rivers have a gross area of 621,275 acres of which 421,000 acres were irrigated in 1929. In the San Joaquin Delta, about 219,000 acres out of a total gross area of 279,000 acres were devoted to irrigated crops in 1929. The water supply for these delta lands, coming partly from the San Joaquin River system and partly from the Sacramento River, has been insufficient in certain months of several recent years to meet the net water requirements and to keep the water in the delta channels fresh as against invasion of saline water from the bay. It is estimated in another report* that the deficiency in supply for the entire delta for meeting the full consumptive demands and preventing saline invasion ranged from about 150,000 to 1,128,000 acre-feet per season with an average seasonal defficiency of 451,000 acre-feet during the period 1920 to 1929.

Except for the San Joaquin Delta the water supplies in the lower San Joaquin Valley under present conditions of development are adequate to meet the present requirements of the irrigated lands. The tendency is for a slight increase of irrigated cropped areas from year to year. It is believed that the area irrigated in 1929 in the lower San Joaquin Valley probably represents the maximum area irrigated at any time up to that year.

With a limited use of ground water in the lower San Joaquin Valley, there has been no general lowering of ground water levels due to pumping in excess of replenishment as in the upper San Joaquin Valley. The depth to ground water is from 5 to 10 feet over a large part of the area irrigated east of the San Joaquin River. Such lower-

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.

ing as has occurred in recent years has been beneficial. North of the Tuolumne River, the depth to ground water over a considerable portion of the area is from 10 to 50 feet and from 50 to 100 feet near the foothills.

Water Requirements.

The uses of water in the San Joaquin River Basin are many. They include domestic, municipal, irrigation, salinity control, industrial, navigation, power development and recreational uses. Of all these uses, however, that for irrigation predominates at the present time and probably will continue to do so. Recreational and navigation uses result in no actual consumption of water and in most instances do not alter the regimen of the stream. The use for development of hydroelectric energy, while altering in some instances the regimen of the stream, does not consume any water. For domestic service alone, the unit use within small cities is practically the same as for irrigation. For industrial and commercial areas in or near municipalities, the amount of water used may be somewhat larger than for the irrigation requirements for an equivalent area. In this basin, the water requirements for present and future ultimate developments have been based on irrigation use. It is believed that on this basis ample water would be provided for all uses except that for salinity control in the Sacramento-San Joaquin Delta. In the State Water Plan, provision for that requirement is made primarily from the Sacramento River Basin.

Water requirements, for any particular area, vary not only in amount with the use to which the water is put, and in monthly demand, but also with the point at which the water is measured. The geographic position of the source of supply in relation to point of use, methods of conveyance, the extent of the area and the opportunity afforded for reuse of water controlled by topographic, geographic and geologic conditions, are factors that have an important bearing on water requirements. For these reasons, variations in treatment of the problems for the different areas necessitated the employment of different terms of use, as follows:

"Irrigation requirement" is the amount of water in addition to rainfall that is required to bring a crop to maturity. This amount varies with the crop to be supplied and the point at which the water is measured. As related to the point of measurement, it is the "gross allowance," "net allowance," or "net use." These terms together with the term "consumptive use" are defined as follows:

> "Gross allowance" designates the amount of water diverted at source of supply.
>
> "Net allowance" designates the amount of water actually delivered to the area served.
>
> "Consumptive use" designates the amount of water actually consumed through evaporation and transpiration by plant growth.
>
> "Net use" designates the sum of the consumptive use from artificial supplies and irrecoverable losses.

In the upper San Joaquin Valley, full development will require importation of water at relatively high costs. It is believed that service under such conditions would be justified only for the better lands. Therefore, in evolving a plan for furnishing a water supply to that region, the area of service has been taken to include only irrigable lands in classes 1 and 2 and a small irrigable area of Class 3 land suitable for citrus development which could be served by diversion from Tule River. The remaining areas of classes 3 and 4 lands classed as irrigable have not been included in the area for service under the State Water Plan for the ultimate development of the upper San Joaquin Valley. This reduces the net irrigable area to be served in the upper San Joaquin Valley from 3,648,000 to 3,135,000 acres on the valley floor and eliminates 41,000 acres of foothill land. In the lower San Joaquin Valley, a region wherein water supplies are adequate if conserved, all classes of irrigable land have been included in estimating the required irrigation supply. This procedure was followed also in estimating the irrigation requirements for lands in the Sacramento River Basin. The net irrigable areas to be served and the water requirements thereof under the ultimate State Water Plan are set forth in the following tabulation. The unit water requirements applied to the irrigable areas to obtain total requirements are based upon data as to present use in the various sections of the basin under the prevailing irrigation methods and conveyance losses. The water requirements for the San Joaquin River Basin (excluding the delta) which would amount to 13,326,000 acre-feet gross allowance if provision were made for the irrigable areas of classes 3 and 4 lands in the upper valley floor and foothills, are reduced to 12,177,000 acre-feet under the adopted plan of service.

SEASONAL WATER REQUIREMENTS OF IRRIGABLE LANDS TO BE SERVED UNDER ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Section	Net irrigable area to be served, in acres	Gross allowance, in acre-feet		Net allowance, in acre-feet		Net use, in acre-feet	
		Average per acre	Total	Average per acre	Total	Average per acre	Total
Upper San Joaquin Valley floor	3,135,000	2.0	6,270,000	2.0	6,270,000	2.0	6,270,000
Lower San Joaquin Valley floor, excluding San Joaquin Delta	1,676,000	3.0	4,968,000	2.2	3,651,000	1.8	3,019,000
Foothill areas	339,000	2.8	939,000	2.0	674,000	1.7	563,000
Totals, excluding San Joaquin Delta	5,150,000	------	12,177,000	------	10,595,000	------	9,852,000
San Joaquin Delta—							
Irrigation and other uses	257,000	(1)	824,000	(1)	824,000	(1)	824,000
Salinity control		------	1,590,000	------	1,590,000	------	1,590,000
Totals, San Joaquin River Basin	5,407,000	------	14,591,000	------	13,009,000	------	12,266,000

[1] Value for net use per unit of area is not given since ultimate total requirements and use are divided among irrigation use, evaporation from delta channels, transpiration from tules and other natural vegetation and evaporation from levees and uncultivated land surfaces.

Major Units of Ultimate State Water Plan in San Joaquin River Basin.

The fundamental objective of the ultimate State Water Plan in the San Joaquin River Basin is to provide and operate works for the conservation, regulation, utilization and distribution of the available water resources so that all areas within the basin, practicable of development, might have adequate water supplies for all purposes and flood protection. A comparison of the available water supplies with the ultimate water requirements of the irrigable areas to be served in the San Joaquin River Basin shows that there is insufficient water to meet the ultimate needs. There would be a large deficiency particularly in the upper San Joaquin Valley where the average seasonal water supply for the 40-year period 1889–1929, exclusive of the San Joaquin River, is but 50 per cent of the ultimate seasonal water requirement. In the lower San Joaquin Valley, excluding the delta, the water supply would be sufficient for ultimate needs. However, in the Sacramento River Basin, studies reveal that there is a surplus of water over its ultimate needs. The logical source of supplemental water supply for the San Joaquin River Basin is the surplus water of the Sacramento River Basin. Therefore, the plans for development in the two basins are interdependent and interrelated and together constitute a unified plan for the entire Great Central Valley. The plan evolved is designed to make the greatest practicable use of the available water supplies in both basins to meet the full requirements for ultimate development in the entire Great Central Valley.

The basic features included in the State Water Plan for the Great Central Valley are storage reservoirs, both surface and underground, and natural and artificial conveyance channels. Surface reservoirs would be constructed on the major streams and operated to equate the erratic run-off in the interest of all uses. Hydroelectric power plants would be installed at those dams where such development would be justified in order to assist in defraying the cost of the capital expenditures. Conveyance channels, both natural and artificial, would transport water supplies from areas having a surplus to areas of deficiency.

Because of the large expense involved in exporting water supplies from the Sacramento River Basin to the San Joaquin Valley, the plan for the San Joaquin River Basin is designed to provide for the fullest practicable utilization of all local water supplies. In addition to surface storage regulation, this necessitates the maximum practicable utilization of underground reservoirs for the storage and subsequent extraction of water supplies. Provision is made for the conveyance and distribution of surplus Sacramento River Basin water, made available by storage and regulation with the major units of the State Water Plan in the Sacramento River Basin, to provide for that portion of the water requirements of the San Joaquin Valley which can not be met by the fullest practicable utilization of local supplies.

Surface Storage Reservoirs—The surface storage reservoir units in the San Joaquin River Basin are thirteen in number, namely, Nashville on Cosumnes River; Ione on Dry Creek, a tributary of Mokelumne River; Pardee on Mokelumne River; Valley Springs on Calaveras River; Melones on Stanislaus River; Don Pedro on Tuolumne River; Exchequer on Merced River; Buchanan on Chowchilla River; Windy Gap on Fresno River; Friant on San Joaquin River; Pine Flat on Kings River; Pleasant Valley on Tule River; and Isabella on Kern River. Power plants are proposed at Melones, Don Pedro, Friant and Pine Flat reservoirs. The Exchequer and Pardee reservoirs with power plants are included in the plan as already constructed and are assumed to be operated for the purposes for which they were designed. The Valley Springs reservoir would be enlarged from 76,000 acre-feet to 325,000 acre-feet capacity, reserving 165,000 acre-feet of space in the reservoir for flood control purposes. At the Melones and Don Pedro reservoirs it is proposed to construct new dams downstream from existing ones, creating reservoirs of larger capacity, and to reconstruct and enlarge the power plants. Flood control features are included in the Nashville, Ione, Valley Springs, Melones, Don Pedro, Exchequer, Friant, Pine Flat and Isabella reservoirs. The aggregate capacity of the surface storage reservoirs proposed for ultimate development is 5,130,000 acre-feet.

Underground Reservoirs—An essential feature of the State Water Plan in the San Joaquin River Basin is the utilization of underground reservoirs for the storage and subsequent extraction of water supplies by pumping. The underground capacity affords the only means of providing the large amount of cyclic storage required to equate the extremely variable run-off and bring the available supply in consonance with the demand and make the fullest practicable utilization of local supplies. Operated in conjunction with surface regulation and distribution, the utilization of the underground reservoirs is shown to result in the cheapest, most flexible and dependable plan of any that has been suggested or investigated. Underground reservoir utilization is particularly important in the upper San Joaquin Valley where experience has already demonstrated its practicability and value and where wells and pumping plants with an aggregate capacity of over 20,000 second-feet already are in operation.

The usable underground capacity in the upper San Joaquin Valley aggregates over 20,000,000 acre-feet and in the lower San Joaquin Valley about 3,000,000 acre-feet. The plan proposes to make full utilization of this underground capacity, particularly in the upper San Joaquin Valley, with operation thereof coordinated with surface storage regulation. The chief cost involved in the utilization of the underground reservoirs would be for the pumping of water supplies. Costs of two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for power charges or a total of five cents per foot acre-foot are representative of the general average for pumping in the San Joaquin Valley.

Conveyance Units—The proposed conveyance units of the ultimate State Water Plan in the San Joaquin River Basin are designed primarily to bring necessary water supplies from the Sacramento River Basin to the San Joaquin Valley to supplement the available local water supplies. The adopted plan of conveyance includes a pumping system on the San Joaquin River to transport water from Sacramento-San Joaquin Delta to Mendota. It provides for the exchange of a portion of the pumped water for San Joaquin River water which would be diverted at the Friant Reservoir, 61 miles farther upstream and 308 feet higher in elevation than the point of delivery of imported water at Mendota. It provides conduits leading north and south from Friant Reservoir to convey San Joaquin

River water to the lands on the eastern slope of the upper San Joaquin Valley. An extension of the pumping system southerly from Mendota is provided to serve the lands on the western slope of the upper San Joaquin Valley. The advantages of the plan are many. Both capital and annual costs would be much less than for conveyance by any other method. By means of the proposed exchange at Mendota, a pumping lift of about 300 feet would be saved over a direct pumping plan. Diversion in the Sacramento-San Joaquin Delta would be effected below all the riparian lands in the Sacramento River Basin. The source of the water supply in the Sacramento-San Joaquin Delta is the temporary catch-basin of the run-off and return water from 42,900 square miles of drainage area, which comprises 74 per cent of the entire area of the Sacramento and San Joaquin River basins and contributes 91 per cent of the run-off of the two basins. Water developed in any part of the two basins north of the upper San Joaquin River would naturally find its way to this catch-basin. The flexibility of the plan would be of great advantage. It would lend itself more readily to progressive development with minimum expenditures and it would interfere least with present rights and interests. By this plan, full recharge of ground water storage would be made by gravity diversion from Friant, whereas any other plan not providing for exchange of water at Mendota would require a greatly increased pumping lift for such purpose. These great advantages would not be attained by any scheme that does not utilize the delta as a source of supply, and only in part, if not combined with exchange with San Joaquin River water.

The conveyance channels, natural and constructed, which would be required for the exportation and delivery of water from the Sacramento River Basin to the lands of the San Joaquin River Basin, would extend from the Sacramento River at the head of Snodgrass Slough to the southern extremity of the San Joaquin Valley.

Beginning at the northerly end of the conveyance system a new connecting channel, in conjunction with a suitable diversion structure in the Sacramento River, is proposed to carry from the Sacramento River to the San Joaquin Delta the water required for exportation to the San Joaquin Valley. It also would convey water for use in the San Joaquin Delta and adjacent uplands and the upper San Francisco Bay region. It would consist of an artificial channel dredged from the Sacramento River at a point just below Hood to the head of Snodgrass Slough, from which point this natural channel would be utilized, with improvements, to Dead Horse Island. The North and South forks of the Mokelumne River would be utilized from there to the San Joaquin River at Central Landing. The length of this cross connection, designated as the Sacramento-San Joaquin Delta Cross Channel, by the shortest route would be 24 miles.

From Central Landing to the first unit of the pumping system below Mossdale bridge, it is proposed to utilize three main channels, each about 30 miles in length. The most easterly of these channels would be the Stockton Deep Water Channel and the San Joaquin River. The other two main channels would be Old River and Salmon Slough, and Middle River with artificial connections already constructed, such as the Victoria-North Canal and the Grant Line Canal. With some enlargement in portions of these channels, the conveyance capacity would be adequate to meet the requirements of irrigation in the delta and adjacent areas and that of exportation to the San Joaquin River Basin.

The first unit of the San Joaquin River Pumping System would be located just above the point of bifurcation of the San Joaquin River and Old River. From this point to the mouth of the Merced River the channel of the San Joaquin River would be utilized for a distance of 72 miles. By means of a series of five successive dams and pumping plants water would be conveyed from the delta and raised to an elevation of 62 feet U. S. Geological Survey datum. The dams used for this portion of the conveyance system would be of the collapsible type so that the river channel could be opened to permit free discharge in case of large flows. The maximum capacity of the pumping system would be 8000 second-feet.

From the pond above Plant No. 5 it is proposed to depart from the river with a constructed canal extending southerly along the most favorable topography. By means of three pumping lifts in a distance of seven miles the water would be raised to an elevation of 137 feet at the discharge of Plant No. 8 and would continue a distance of sixteen miles to Plants No. 9 and No. 10, about five miles west of Los Banos. An exchange would be made with existing systems serving lands lying below Plant No. 9. From the discharge of Plant No. 10, at an elevation of 180 feet, the canal would extend southerly about 38 miles to the Mendota weir, delivering water to an elevation of 159 feet. The total distance from Pumping Plant No. 1 to Mendota weir would be 135 miles. The pond above the Mendota weir would be the source of supply for lands now served by diversion at and near this point. A small part of the Columbia area would be served by pumping.

The delivery of imported waters to Mendota to meet the demand of existing rights would make possible the diversion at the Friant Reservoir of the flow of the San Joaquin River for use on the eastern slope of the upper San Joaquin Valley. To effect such diversion it is proposed to construct, in addition to the Friant Reservoir, two main canals, one on each side of the San Joaquin River. The Madera Canal, with a diversion capacity of 1500 second-feet, on the north side of the river would extend for eighteen miles to the channel of the Fresno River. The San Joaquin River-Kern County Canal on the south side of the stream would extend southward along the eastern rim of the valley a distance of 165 miles. With a diversion capacity of 3000 second-feet at the Friant Reservoir, it would cross in turn the channels of the Kings, Kaweah, Tule and Kern rivers, terminating at the Kern Island Canal, with a capacity of 500 second-feet.

In order to utilize Kern River waters released by the importation of new supplies, it would be necessary to construct the Kern River Canal with a diversion point near the mouth of the canyon on the south side of the stream and extending under the Kern Mesa and thence around the south end of the valley to Buena Vista Valley. The maximum diversion capacity of this canal would be 1500 second-feet and the total length 75 miles.

To make water available for the good land lying on the western slope of the upper San Joaquin Valley, the Mendota-West Side Pumping System is provided extending from Mendota Pool to Elk Hills. Water for this area would be imported through the San Joaquin River Pumping System. An essential element of such a system would be a conveyance channel which, for full development, would be 100 miles long and have a capacity varying from 4500 to 500 second-feet. It would terminate at an elevation of 250 feet.

Capital and Annual Costs—Estimates of both the capital and annual costs were made for each surface storage and conveyance unit, based on the costs of labor and materials as of 1929 and 1930 and on the assumption that each unit would be completely constructed in one step. The following tabulation sets forth the capital and net annual costs of all major surface storage and conveyance units in the San Joaquin River Basin. Four of the reservoirs include power plants. The capital cost of each of these reservoirs includes power features. The net annual cost consists of the annual cost of the reservoir and the gross annual cost of the power plant less the estimated average annual revenue from the sale of electric energy. Two of the conveyance units include pumping systems. The annual cost of each of these units includes the estimated average annual cost of electric energy required for pumping.

COSTS OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Location	Capital cost	Net annual cost
Storage Units—			
Nashville Reservoir	Cosumnes River	$7,400,000	$441,000
Ione Reservoir	Dry Creek	8,600,000	517,000
Pardee Reservoir	Mokelumne River	Constructed	Constructed
Valley Springs Reservoir	Calaveras River	7,600,000	452,000
Melones Reservoir[1]	Stanislaus River	26,200,000	937,000
Don Pedro Reservoir[1]	Tuolumne River	32,500,000	979,000
Exchequer Reservoir	Merced River	Constructed	Constructed
Buchanan Reservoir	Chowchilla River	2,600,000	155,000
Windy Gap Reservoir	Fresno River	3,300,000	200,000
Friant Reservoir[2]	San Joaquin River	14,500,000	805,000
Pine Flat Reservoir[1]	Kings River	11,600,000	541,000
Pleasant Valley Reservoir	Tule River	2,900,000	171,000
Isabella Reservoir	Kern River	5,700,000	340,000
Subtotals		$122,900,000	$5,538,000
Conveyance Units—			
Sacramento-San Joaquin Delta Cross Channel	Sacramento-San Joaquin Delta	$4,000,000	$300,000
San Joaquin River Pumping System	Lower San Joaquin Valley	28,500,000	[3]6,779,000
Mendota-West Side Pumping System	West side Upper San Joaquin Valley	16,000,000	[4]3,088,000
Madera Canal	East side Upper San Joaquin Valley, north of San Joaquin River	2,500,000	213,000
San Joaquin River-Kern County Canal	East side Upper San Joaquin Valley, south of San Joaquin River	28,000,000	2,281,000
Kern River Canal	East side and south end of Upper San Joaquin Valley, south of Kern River	9,000,000	721,000
Subtotals		$88,000,000	$13,382,000
Totals, all units		$210,900,000	$18,920,000

[1] Includes power plant.
[2] Includes power plant for ultimate development, only.
[3] Includes energy cost of $4,240,000.
[4] Includes energy cost of $1,692,000.

Operation and Accomplishments—Because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for a portion of the supply required to meet its ultimate requirements, consideration of the operation and accomplishments of the plan in the San Joaquin River Basin must be combined with those in the Sacramento River Basin. The proposed major units for ultimate development in the two basins constitute a unified project for the entire Great Central Valley, and these major units would be operated coordinately to provide the ultimate water requirements and to accomplish the objectives sought for the fullest practicable conservation, regulation, distribution and utilization of the water resources. The proposed major units in the Sacramento River Basin would be operated not only to take care of the requirements for all purposes within that basin itself but also to provide the supplemental supply required in the San Joaquin River Basin, including the San Joaquin Delta and the adjacent delta uplands. Provision would also be made to supply the water requirements of the upper San Francisco Bay region with water furnished chiefly from the Sacramento River Basin. Details as to the operation of the major units in the Sacramento River Basin are set forth in another report.*

In the lower San Joaquin Valley the proposed surface storage reservoirs on the Cosumnes, Calaveras and Mokelumne rivers and Dry Creek, a tributary of the Mokelumne River, would be operated coordinately with storage units on the American River in the Sacramento River Basin so that the combined amount of water obtained from these local sources and from the supplies imported from the American River would meet the ultimate water requirements of the irrigable area to be served by these streams. The surface reservoirs on the Stanislaus, Tuolumne and Merced rivers would be operated to provide an adequate surface irrigation supply for all irrigable lands to be served in their respective service areas. However, a portion of the service area under the Merced River would be supplied in part through ground water storage and pumping and in part from water conveyed through the San Joaquin River Pumping System. For the bulk of the area on the east side of the upper San Joaquin Valley from the Chowchilla River to the southern end, the surface storage reservoirs would be operated in combination with ground water storage and pumping to provide a full supply in all years to the irrigable area to be served under ultimate development. To accomplish the desired results would require the operation of the underground reservoirs in a specific manner similar to that of surface reservoirs. Water would be stored in the underground reservoirs when the available supplies are in excess of the net requirements. The supplies stored underground would be drawn upon for the most part through the medium of privately owned pumping plants. However, in order to maintain a balance in supply and draft over long periods throughout the areas to be supplied in part by ground water, works for the distribution of surplus waters, and pumping equipment in strategic locations, necessarily would be controlled and operated by recognized local public agencies. Friant Reservoir would be operated as a key unit for the entire area on the east side

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

of the upper San Joaquin Valley to provide the necessary supplies to supplement the amounts made available from local sources through surface and underground storage regulation. The supplies from this reservoir would be distributed through the Madera and San Joaquin River-Kern County canals.

The areas to be served on the westerly slope of both the upper and lower San Joaquin Valley would be supplied by water conveyed through the San Joaquin River and Mendota West-Side Pumping systems. The source of water supply would be chiefly surplus Sacramento River Basin water conveyed from the delta channels through these pumping systems to the southerly terminus near Elk Hills. An additional source of supply would be the return flows from irrigated lands in the lower San Joaquin Valley and unregulated surplus water of the San Joaquin River and its east side tributaries, which would be intercepted in that portion of the San Joaquin River Pumping System utilizing the river channel below the mouth of the Merced River. The interception and utilization of these return and surplus waters would reduce the capital and annual costs of the pumping system. However, the amounts intercepted would necessarily be replaced in the delta by Sacramento River Basin water in order to provide for delta requirements and hence the amount of supplemental water supply required from the Sacramento River Basin for the San Joaquin Valley would not be reduced by the interception and utilization of these return and surplus waters.

Based upon a detailed monthly analysis of the proposed plan of operation with the available water supplies during the 40-year period 1889–1929, the water supplies which would be made available to meet the water requirements under the ultimate State Water Plan in the San Joaquin River Basin may be summarized as follows:

1. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of a net area of 1,810,000 acres of irrigable land in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley, after deducting from the full natural run-off of the lower San Joaquin River tributaries, 565,000 acre-feet per season for an adequate and dependable irrigation supply for 205,000 acres of land embracing all of the net irrigable mountain valley and foothill lands situated in the lower San Joaquin Basin at elevations too high to be irrigated by gravity from the major reservoir units.
2. A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of classes 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley.
3. A supply of 1,570,000 acre-feet per season, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of all of the net irrigable area of 772,000 acres of classes 1 and 2 lands lying on the western slope of the upper San Joaquin Valley and 13,000 acres of classes 1 and 2 lands in the Columbia Canal area.

In addition to the water supplies furnished from the local streams in the San Joaquin River Basin, there would have been required from the Sacramento River Basin an average seasonal supply of about 2,000,000 acre-feet, exclusive of about 1,000,000 acre-feet of return flow and surplus water from the lower San Joaquin Valley intercepted and utilized in the San Joaquin River Pumping System, which would be replaced in the delta by Sacramento River Basin water. The required supplemental supply for the San Joaquin Valley would have been provided by the proposed major units in the Sacramento River Basin, including the Trinity River diversion, in addition to providing the full ultimate requirements in the Sacramento River Basin itself, the full requirements in the Sacramento-San Joaquin Delta including control of salinity and maintenance of fresh water in the delta channels, and the provision of supplemental supplies for the upper San Francisco Bay region.

In addition to the water supplies furnished, an average annual energy output of 728,500,000 kilowatt hours would be generated at the major reservoirs in the San Joaquin River Basin incidental to their primary operation for irrigation; additional flood protection would be effected on several of the major streams; and navigation would be improved on the San Joaquin River above Stockton.

Initial Development of State Water Plan in San Joaquin River Basin.

The initial development of the State Water Plan in the San Joaquin River Basin is proposed as the first progressive step in the consummation of the plan for ultimate development. It is designed primarily to meet the immediate pressing needs of existing developments. Certain areas in the basin, particularly in the upper San Joaquin Valley and in the San Joaquin Delta region, have serious problems of water shortage as previously described in this chapter. The adequate solution of these problems to maintain the productive resources and investments of present developments would require the construction and operation of initial units of the State Water Plan. In addition to providing supplies to meet present deficiencies, additional flood protection and improvement of navigation on the San Joaquin River above Stockton are desirable.

In the developed areas on the east side of the upper San Joaquin Valley, studies of water supply and water requirements during the period 1921–1929 reveal that the average seasonal deficiency in water supply during this period amounted to 387,000 acre-feet. The area involved aggregates about 400,000 acres of fully developed and irrigated lands. Water supplies are obtained largely by pumping from underground and the depletion of the underground reservoirs has resulted in a general lowering of ground water levels causing excessive pumping lifts in some localities. Supplemental water supplies are required to meet not only the deficiencies between supply and demand but also to replenish the underground reservoirs and reduce pumping lifts. It is estimated that an average seasonal importation of supplemental water of from 500,000 to 600,000 acre-feet should be provided as a minimum requirement.

In the San Joaquin Delta a developed irrigated area of 219,000 acres has experienced a deficiency in water supply to meet the net water requirements for irrigation and to keep the water in the delta channels fresh as against invasion of saline water from the bay. Supplemental water supplies are required to meet the deficiency in this area and in the Sacramento River portion of the delta as well, which is estimated to have averaged 451,000 acre-feet annually during the period 1920–1929. In addition there is an immediate need of supplemental water supplies for present industrial and agricultural developments in the upper San Francisco Bay region adjoining the delta.

The plan for initial development to provide supplemental supplies to the upper San Joaquin Valley has been considered in two steps, first, an immediate initial development to provide an average seasonal supplemental supply of 500,000 to 600,000 acre-feet during a similar period of run-off such as 1921–1929, and, second, a complete initial development to furnish a larger supplemental water supply and provide with greater certainty for the complete relief of present developed areas, more substantial ground water replenishment, and for some expansion of irrigated areas on lands adjacent to present developments. The provision of supplemental supplies for the Sacramento-San Joaquin Delta and adjacent areas also would be required under both the immediate and complete initial plans of development. The plan for initial development in the San Joaquin River Basin involves initial units in the Sacramento River Basin which would be required to provide for the immediate requirements of the delta and adjacent areas and for supplemental water supplies required in the upper San Joaquin Valley for complete initial development. The units for initial development in the two basins constitute a unified project for the entire Great Central Valley.

For the relief of the areas of deficient water supply in the upper San Joaquin Valley, it is proposed in the plan for immediate initial development to acquire, by purchase of existing rights, waters of the San Joaquin River now devoted to inferior use on "grass lands" for pasture, served by diversions from this river above the mouth of the Merced River. The water so acquired together with surplus water of the San Joaquin River would be regulated in Friant Reservoir and conveyed to the areas in the upper San Joaquin Valley through the Madera and San Joaquin River-Kern County canals. Based on the period of run-off from 1921 to 1929, sufficient water to meet the present deficiencies could be obtained from this source for the upper San Joaquin Valley at a cost less than that from any other source.

The proposed physical works in the San Joaquin River Basin for immediate initial development comprise the following:

1. Friant Reservoir with a gross capacity of 400,000 acre-feet and a usable capacity of 270,000 acre-feet above elevation 467 feet. diversion elevation of San Joaquin River-Kern County canal.
2. San Joaquin River-Kern County canal to Kern River with a maximum diversion capacity of 3000 second-feet.
3. Madera canal with a maximum capacity of 1500 second-feet.
4. Magunden-Edison pumping system with a capacity of 20 second-feet.

After providing an adequate water supply from the San Joaquin River to meet the demands of crop lands now served from this stream above the mouth of the Merced River in accord with present rights, the average seasonal amounts of water that could have been obtained from regulation of surplus and "grass land" waters in Friant Reservoir and delivered through the conduits diverting therefrom would have been of the following amounts for different periods from 1889–1929.

Period	*Supply for areas served by San Joaquin River-Kern County Canal, average seasonal amount, in acre-feet*	*Supply for Madera area, average seasonal amount, in acre-feet*	*Total average seasonal amount, in acre-feet*
1889–1929	851,000	181,000	1,032,000
1909–1929	688,000	151,000	839,000
1917–1929	495,000	107,000	602,000
1919–1929	485,000	108,000	593,000
1921–1929	493,000	108,000	601,000
1924–1929	410,000	90,000	500,000

The allocation of the supplemental water supplies furnished from Friant Reservoir to the areas requiring immediate relief on the east side of the upper San Joaquin Valley would be based not only upon the average deficiencies in supply but also upon the needs for ground water replenishment in the absorptive areas where ground water supplies are utilized.

If it should prove desirable and necessary to furnish a direct surface supply from imported water from the San Joaquin River to lands lying to the east of Tulare Lake in Kings County, now used chiefly for the growing of annual crops and having a variable water supply, water would be available for this purpose, however, with a reduction of supply to the other counties. It is estimated that 90,000 acre-feet seasonally would be adequate for the irrigation of the lands now cropped.

Studies of the operation of Friant Reservoir under the plan of immediate initial development, with the water supplies obtained therefrom combined with local supplies in the upper San Joaquin Valley and with regulation of local and imported supplies from the San Joaquin River effected by underground storage and pumping, show that during the period 1921–1929 the present water requirements would have been fully met and there would have been 1,361,000 acre-feet more water available in the underground reservoirs at the end of the period than at the beginning.

When water supplies in addition to the amounts made available from the proposed plan of immediate initial development are required in the upper San Joaquin Valley, either for the purpose of more adequately meeting the needs of present developed areas for actual water requirements and ground water replenishment or for expansion of irrigated areas or for both purposes, importation of Sacramento River Basin water will be required. The additional units required for this purpose would comprise the Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System with an initial maximum capacity of 3000 second-feet. It is considered that this would be a second step in the initial development and it is believed that the construction of the conveyance units required for importation of Sacramento River Basin water to the San Joaquin Valley could be deferred. However, in view of the possibility of the occurrence of seasons or periods of run-off even more subnormal than during the period 1921–1929 and the resulting possible need of supplemental water supplies from the Sacramento River Basin to adequately meet the present needs of developed areas, provision should be made in the plan of financing for the initial development to meet the cost of these additional units.

Under the plan of complete initial development water supplies made available from the surplus in the Sacramento River Basin would be conveyed from the delta to Mendota sufficient in amount to provide a full supply for the crop lands now served from the San Joaquin River above the mouth of Merced River. Practically the entire flow of the San Joaquin River at Friant would be regulated in Friant Reservoir for utilization on the east side of the upper San Joaquin Valley. Based on the run-off during the 12-year period 1917–1929, the average seasonal supply from Friant Reservoir would have been 1,366,000 acre-feet. This supply combined with the utilizable supplies from the unregulated local streams in the upper San Joaquin Valley, would amount to 3,574,000 acre-feet average per season and would have been sufficient to irrigate about one and one-half times the present irrigated area now supplied from local streams on the east side of the upper San Joaquin Valley.

Economic and Financial Aspects—Consideration of the economic and financial aspects of the initial plan of development in the San Joaquin River Basin must be combined with the initial plan in the Sacramento River Basin because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for a portion of the water supply required. The units in the two basins comprise a unified project for the entire Great Central Valley. Analyses of cost, anticipated revenues and plans of financing have, therefore, been made for the initial State Water Plan in the entire Great Central Valley. In addition to the units in the San Joaquin River Basin, the initial plan of development in the Great Central Valley would include Kennett Reservoir (capacity 2,940,000 acre-feet) and power plants on the Sacramento River and a conduit to convey water from the delta to the upper San Francisco Bay area.

The capital and gross annual costs of the proposed units of the initial State Water Plan in the Great Central Valley are shown in the following tabulation. Capital costs include interest at 4½ per cent during construction, and annual costs include interest at 4½ per cent, amortization on 4 per cent sinking fund basis in 40 years, depreciation, and operation and maintenance expense.

CAPITAL AND ANNUAL COSTS OF INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY

Item	Immediate initial development		Complete initial development	
	Capital cost	Gross annual cost	Capital cost	Gross annual cost
Kennett reservoir and power plant	$84,000,000	$5,297,000	$84,000,000	$5,297,000
Sacramento-San Joaquin Delta cross channel			4,000,000	300,000
Contra Costa County conduit	2,500,000	300,000	2,500,000	300,000
San Joaquin River pumping system			15,000,000	2,500,000
Friant reservoir and power plant	15,500,000	1,062,000	14,500,000	885,000
Madera Canal	2,500,000	213,000	2,500,000	213,000
San Joaquin River-Kern County Canal	27,300,000	2,225,000	27,300,000	2,225,000
Magunden-Edison pumping system	100,000	18,000	100,000	18,000
Water rights and general expense	7,000,000	389,000	8,000,000	444,000
Total costs	$138,900,000	$9,504,000	$157,900,000	$12,182,000

Direct revenues would be derived from sale of electric energy and water under the operation of the initial State Water Plan. The anticipated revenues from sale of electric energy and water, based upon the estimated amounts of electric energy and water which would be sold, are set forth in the following tabulation:

AVERAGE ANNUAL REVENUES OF INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY

Source of revenue	Immediate initial development		Complete initial development	
	Annual output, in kilowatt hours	Revenue	Annual output, in kilowatt hours	Revenue
Electric energy sales—				
Kennett, including Keswick	1,591,800,000	$4,218,000	1,581,100,000	$3,826,000
Friant, river plant	105,000,000	367,000		
Friant, Madera Canal plant			23,000,000	80,000
Subtotals	1,696,800,000	$4,585,000	1,604,100,000	$3,906,000
Water sales—	Annual delivery, in acre-feet	Revenue	Annual delivery, in acre-feet	Revenue
Upper San Joaquin Valley	600,000	$1,800,000	1,720,000	$5,160,000
Contra Costa County	43,500	300,000	43,500	300,000
Sacramento-San Joaquin Delta and Sacramento River	420,000	420,000	420,000	420,000
Subtotals	1,063,500	$2,520,000	2,183,500	$5,880,000
Total electric energy and water sales		$7,105,000		$9,786,000

With interest at $4\frac{1}{2}$ per cent and amortization of the capital investment in 40 years, the gross annual cost of the initial State Water Plan in the Great Central Valley exceeds the anticipated revenues from the sale of water and power by over $2,000,000. However, in addition to the direct anticipated revenues, it is believed that the large benefits which would accrue to the many interests, not only local but also national and state-wide, might reasonably justify the anticipation of direct contributions by the Federal and State governments to defray a portion of the cost of the project. It also is possible that the project could be financed at a lower average rate of interest and with repayment extended over a longer period than that assumed in the estimated gross annual costs as previously presented. Such modifications might reduce the gross annual cost, including interest and amortization on capital expenditures to be directly borne by the project, to such an extent that the revenues would be sufficient to meet the annual carrying charges. The analyses of several tentative plans of financing based upon various assumed interest and sinking fund rates, amortization periods and Federal and State contributions are summarized in the following tabulation:

FINANCIAL ANALYSES OF INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY WITH VARIOUS ASSUMED BASES OF FINANCING

Annual Direct Revenues from Sale of Water and Electric Energy: Immediate Initial Development, $7,105,000; Complete Initial Development, $9,786,000

Basis of financing	Immediate initial development			Complete initial development		
	Capital cost	Gross annual cost	Net annual cost (—) or return (+)	Capital cost	Gross annual cost	Net annual cost (—) or return (+)
Without direct Federal or State Contributions—						
Plan 1. Interest at 4½ per cent and 40-year amortization on a 4 per cent sinking fund basis	$138,900,000	$9,504,000	—$2,399,000	$157,900,000	$12,182,000	—$2,396,000
Plan 2. Interest at 4½ per cent and 50-year amortization on a 4 per cent sinking fund basis	138,900,000	8,960,000	—1,855,000	157,900,000	11,556,000	—1,770,000
Plan 3. Interest at 4½ per cent and 70-year amortization on a 4 per cent sinking fund basis	138,900,000	8,438,000	—1,333,000	157,900,000	10,956,000	—1,170,000
Plan 4. Interest at 4 per cent and 50-year amortization on a 4 per cent sinking fund basis	137,400,000	8,179,000	—1,074,000	156,200,000	10,649,000	—863,000
Plan 5. Interest at 3½ per cent and 50-year amortization on a 3½ per cent sinking fund basis	136,000,000	7,564,000	—459,000	154,700,000	9,945,000	—159,000
Plan 6. Interest at 3 per cent and 50-year amortization on a 3 per cent sinking fund basis	134,500,000	6,975,000	+130,000	152,900,000	9,253,000	+533,000
Plan 7. No interest and repayment of principal sum in 40 equal annual installments	125,400,000	4,767,000	+2,338,000	142,900,000	6,673,000	+3,113,000
With direct Federal and State contributions—						
Plan 8. Same as Plan 1, with direct Federal contribution of $6,000,000 in the interest of navigation and State contribution of $3,400,000 for the relocation of State highway above Kennett Reservoir	*$129,500,000	$8,980,000	—$1,875,000	*$148,500,000	$11,658,000	—$1,872,000
Plan 9. Same as Plan 2, with Federal and State contributions as in Plan 8	*129,500,000	8,475,000	—1,370,000	*148,500,000	11,071,000	—1,285,000
Plan 10. Same as Plan 3, with Federal and State contributions as in Plan 8	*129,500,000	7,989,000	—884,000	*148,500,000	10,507,000	—721,000
Plan 11. Interest at 4½ per cent and refunding bonds, with same Federal and State contributions as in Plan 8	*129,500,000	7,512,000	—407,000	*148,500,000	10,099,000	—313,000
Plan 12. Same as Plan 5, with Federal and State contributions as in Plan 8	*126,600,000	7,188,000	—83,000	*145,300,000	9,613,000	+173,000
Plan 13. Same as Plan 12, with Federal contribution increased to $20,000,000	*112,600,000	6,591,000	+514,000	*131,300,000	9,016,000	+770,000

*Direct Federal and State contributions not included.

NOTE.—If financed under the provisions of Title II of the National Industrial Recovery Act of 1933, with a direct Federal contribution of 30 per cent of the cost of labor and materials and a Federal loan to finance the balance of the cost with interest at 4 per cent and amortization on a 4 per cent sinking fund basis in 50 years, the gross annual cost of the project for complete initial development would be considerably less than the anticipated revenue from water and power sales.

Flood Control.

Under natural conditions, about one and three-quarters million acres of land in the San Joaquin River Basin is subject to inundation by floods. About half of this flooded area has been protected in varying degree by flood control works, chiefly comprising levees. These works have been constructed almost entirely by local interests. No general plan of flood control has been adopted in the San Joaquin Valley such as that in the Sacramento Valley. More adequate flood protection is needed in many of the areas now partially protected from floods, and flood control works for lands now unprotected will be necessary and desirable.

One of the important objectives of the State Water Plan in the San Joaquin River Basin is the provision of additional flood protection to reduce flood hazards on the areas subject to flooding. It is proposed to reduce flows by surface reservoir regulation, thereby increasing the degree of protection on lands now leveed and reducing the cost of additional levee protection. The reservation of space and its operation for flood control is provided for in most of the major reservoirs. The following tabulation sets forth the streams on which flood control by reservoirs is proposed, the maximum reservoir space required to regulate floods to certain controlled flows, the amounts of these controlled flows and the frequency with which the controlled flows would be exceeded. The operation of these reservoirs for flood control would not materially impair their value for conservation purposes, nor materially decrease the amount or value of electric energy generated by water released from them.

RESERVOIR SPACE REQUIRED FOR CONTROLLING FLOODS TO CERTAIN SPECIFIED FLOWS

Reservoir	Stream	Point of control	Maximum reservoir space employed, in acre-feet	Controlled flow, in second-feet[2]
Nashville	Cosumnes River	Michigan Bar	56,000	15,000
Ione	Dry Creek	Galt	[1]121,000	5,000
Pardee	Mokelumne River	Clements	[1]0	10,000
Valley Springs	Calaveras River	Jenny Lind	165,000	25,000
Melones	Stanislaus River	Knights Ferry	204,000	15,000
Don Pedro	Tuolumne River	La Grange	214,000	15,000
Exchequer	Merced River	Exchequer	59,000	25,000
Friant	San Joaquin River	Friant	75,000	15,000
Pine Flat	Kings River	Piedra	80,000	15,000
Isabella	Kern River	Bakersfield	67,000	7,500

[1] Floods which would cause flows in excess of 10,000 second-feet in the Mokelumne River at Clements would be diverted from the Pardee Reservoir to Dry Creek by the Jackson Creek spillway and the water stored in Ione Reservoir.
[2] Controlled flow would be exceeded once in 100 years on the average.

The operation of the foregoing reservoirs for flood control, employing the reservoir space reserved in each reservoir for the specific purpose of controlling floods to the specified flows, would result in a substantial reduction of flood flows at points of concentration along the areas subject to inundation. The following table sets forth, for various points on the San Joaquin River, the crest flood flow exceeded once in 100 years, with and without reservoir control. The flows without reservoir control are those that would obtain with levees constructed along the San Joaquin River from Herndon to the delta to form a channel of sufficient width to care for these flows and reclaim the remaining land now subject to overflow. The flows with reservoir control are those that would obtain with the same channel, but with the flood flows from the larger streams controlled by means of regulation to those shown in the foregoing tabulation. If reclamation of the valley lands by means of levees were not effected until after the reservoirs with flood control features were completed, a narrower flood channel along the river could be constructed because of the smaller regulated flows. Under this condition, however, the flows might be slightly larger than those shown in the last column of the following tabulation, since the reduction of quantities by storage in the narrower channels might be less and the rate of concentration somewhat greater.

FLOOD FLOWS IN SAN JOAQUIN VALLEY WITH AND WITHOUT RESERVOIR CONTROL

Point of concentration	Crest flood flow in second-feet, exceeded once in 100 years on the average	
	Without reservoir control	With reservoir control
San Joaquin River below confluence with Merced River	70,000	51,000
San Joaquin River below confluence with Tuolumne River	103,000	64,000
San Joaquin River below confluence with Stanislaus River	133,000	82,000
Combined concentrations Sacramento and San Joaquin rivers—opposite Collinsville	780,000	595,000

It is estimated that the reduction in flood flows by reservoir control as proposed under the State Water Plan would effect a probable minimum saving of about $18,000,000 in cost of flood protection works in the San Joaquin Valley.

Navigation.

In the formulation of the State Water Plan for the coordinate development and utilization of the water resources of the Great Central Valley, consideration has been given to the need for water transportation and the feasibility of further improvement of navigation. Within the San Joaquin River Basin, the navigable waterways comprise the main San Joaquin River, the tributary Mokelumne River and many miles of interconnecting natural and artificial channels in the San Joaquin Delta. The Federal Government has recognized these streams as navigable waterways since the seventies and has exercised jurisdiction over them, through the Corps of Engineers of the United States War Department, in the interest of improvement and maintenance of navigation.

In accord with investigations made by the United States War Department, the portion of the San Joaquin River which is worthy of consideration with a view to further improvement in the interest of navigation lies between Stockton and Mendota. This river offers a potential inland waterway through the heart of the San Joaquin Valley which, if adequately improved, would provide a means of cheap water transportation for the large and increasing volume of tonnage moving to and from the San Joaquin Valley. The lower section of the river below Stockton has been improved to provide dependable navigation for commercial craft and is functioning as one of the most important and successful internal waterways in the nation. About one million tons of freight valued at nearly 43 million dollars are moved annually on this waterway. A deep water channel to Stockton, which will accommodate ocean going vessels, is expected to be completed early in 1933, thus adding Stockton as a port in the San Francisco Bay Harbor. On the section of the river above Stockton, commercial craft in former years, starting as early as the fifties, navigated as far up stream as Mendota and occasionally to Herndon. However, navigation has always been seasonal in character because of the greatly reduced stream flow during several months of the year when navigation is not practicable. The lack of dependable navigation depths has discouraged water transportation and there has been no commercial navigation of importance for many years on the San Joaquin River above Stockton.

The plan recommended by the Division Engineer, Pacific Division, United States War Department for the improvement of navigation on the San Joaquin River from Stockton to Mendota provides for the canalization of the waterway by the construction of movable dams equipped with locks to maintain a minimum navigable depth of six feet. The Division Engineer estimates the capital cost at $12,000,000 of which $6,000,000 is for the estimated cost of the locks alone; and the annual cost of maintenance and operation at $110,000. The economic value of improvement, based upon estimates of probable savings in transportation costs which would be effected by the proposed improvement, is estimated by the Division Engineer at nearly $6,000,000 or an amount sufficient to justify about half of the capital expenditure required. It is believed, however, that a more comprehensive analysis of potential savings in transportation cost than that made by the Division Engineer might show an economic value sufficient in amount to justify the entire capital expenditure required for the plan of canalization from Stockton to Mendota.

The plan for conveyance of water from the delta to Mendota provided under the State Water Plan could be effectively coordinated with the plan for navigation improvement of the upper San Joaquin River. The plan as proposed for the San Joaquin River Pumping System would canalize the river from the delta to Salt Slough and would provide slack water navigation if the dams were equipped with locks. Above Salt Slough, this conveyance unit would depart from the river in accord with the most economical location and plan determined from detailed studies of alternate plans and routes. However, if sufficient funds were made available in the interest of navigation to pay for the cost of locks and a portion of the dams for a combined canalization and conveyance project on the San Joaquin River from Stockton to Mendota, it would be desirable and advantageous to adopt an all-river channel route for the San Joaquin River Pumping System and thus combine conveyance of water and navigation improvements in one system of works with resulting economy for both purposes.

Conclusions.

1. The water supply originating in the San Joaquin River Basin, which could be made available and utilized under the fullest practicable development, is insufficient in amount to meet the ultimate water requirements for all uses in the basin.

2. The greatest practicable utilization of the available capacity of underground reservoirs particularly in the upper San Joaquin Valley for storage and subsequent extraction of water is essential for effecting the required maximum conservation and utilization of the available local water supplies and reducing the amount of water required to be imported from outside the basin. The use of underground storage in conjunction with surface storage reservoirs offers the cheapest and most feasible method of water conservation and utilization.

3. The logical source of supplemental water supply for the San Joaquin River Basin is in the Sacramento River Basin, where surplus water in excess of the amount required for all uses in the complete ultimate development of that basin could be provided by a full practicable development of the available water supplies therein with the addition of regulated supplies diverted from the Trinity River.

4. The most feasible and least expensive plan for importing water from the Sacramento River Basin to the upper San Joaquin Valley and the one involving the least interference with existing rights and minimum legal difficulties, is one which would provide for pumping from the Sacramento-San Joaquin Delta channels up the San Joaquin River.

5. The plans for water supply development in the Sacramento and San Joaquin River basins must be combined under a unified project for the entire Great Central Valley, with all units of the project operated coordinately to effect the greatest conservation, regulation and utilization of the available water supplies to meet the needs for all purposes in both basins.

6. The proposed major units of the ultimate State Water Plan in the Great Central Valley combined with underground storage in the San Joaquin Valley, operated coordinately under conditions of stream flow equivalent in amount and distribution to that during the dry period 1917–1929 reduced by ultimate net use requirements in the mountain and foothill areas above the major reservoir units, would furnish adequate and dependable irrigation supplies for all irrigable lands in the Great Central Valley, would reduce flood flows in the major streams, would improve navigation on the Sacramento and San Joaquin rivers, would maintain a flow past Antioch into Suisun Bay sufficient to prevent invasion of saline water in harmful degree into the Sacramento-San Joaquin Delta channels, and would furnish a supply of water to the San Francisco Bay Basin to supplement water supplies in that basin for irrigation and industrial uses.

7. Under present conditions of water supply development and utilization, the available water supply in the San Joaquin River Basin is inadequate to meet the water requirements of fully developed and producing irrigated lands, particularly in the southern San Joaquin Valley where the supply for 400,000 acres of irrigated crops is only half that required, and in the San Joaquin Delta and adjacent uplands where the supply is insufficient to meet the requirements for about 300,000 acres of irrigated crops together with other consumptive demands and to prevent invasion of saline water from the bay into the delta channels.

5—80997

8. A minimum supplemental water supply of about one-half million acre-feet average per season would be required to meet the deficiencies in supply in the present developed area of 400,000 acres in the upper San Joaquin Valley and to replenish the diminishing ground water supplies, based upon the water supply available during the period 1921–1929.

9. Based upon the stream flow into the Sacramento-San Joaquin Delta during the period 1920–1929, a supplemental supply averaging 451,000 acre-feet and ranging from a minimum of 150,000 acre-feet to a maximum of 1,128,000 acre-feet per season during that period would be required to meet the present consumptive use requirements in the delta and prevent saline invasion. About two-thirds of this supply would be required in the San Joaquin Delta.

10. The utilization by storage and regulation at Friant Reservoir of the surplus waters in the upper San Joaquin River and waters to be made available through purchase of water rights attached to so-called "grass lands" on the San Joaquin River would furnish an adequate and also the least expensive supply to be secured by an initial step for the relief of the present developed areas of permanent deficiency in water supply in the upper San Joaquin Valley, based upon the stream flow during the period 1921–1929; but the feasibility of this plan would be contingent upon the effective control of salinity and the meeting of consumptive use requirements in the Sacramento-San Joaquin Delta by the development of storage in the Sacramento River Basin to furnish regulated supplemental supplies for this purpose.

11. The units proposed for immediate development of the initial State Water Plan in the Great Central Valley (Kennett and Friant reservoirs, the San Joaquin River-Kern County Canal, the Madera Canal, Magunden-Edison Pumping System and the Contra Costa County Conduit) would furnish adequate water supplies for present needs in the Sacramento Valley, Sacramento-San Joaquin Delta and upper San Francisco Bay region, and upper San Joaquin Valley, would increase the degree of flood protection and improve navigation on the Sacramento River, and incidentally would generate an annual average of 1,696,800,000 kilowatt hours of hydroelectric energy.

12. When water supplies in addition to the amounts made available by regulation in Friant Reservoir of surplus and "grass land" waters of the San Joaquin River are required in the San Joaquin Valley, either for more adequately meeting the requirements of present developed areas and providing more substantial ground water replenishment, or providing for expansion of irrigation areas, or for both, importation of water from the Sacramento River Basin would be required. Such additional supplies could be made available in the Sacramento-San Joaquin Delta channels through the operation of the initial storage unit (Kennett Reservoir on the Sacramento River) of the State Water Plan in the Sacramento River Basin, from surplus water in excess of the present needs of the Sacramento Valley, Sacramento-San Joaquin Delta and adjacent upper San Francisco Bay Basin.

13. The second step in the initial State Water Plan in the Great Central Valley, designated the "complete initial" development, would

require the Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System to convey Sacramento River water to the upper San Joaquin Valley. It is believed these units would not be required immediately but provision should be made in any plan of financing for initial development for funds to defray the cost of these units.

14. Improvement of navigation on the San Joaquin River above Stockton could be effected by the incorporation of locks in the dams of that portion of the San Joaquin River Pumping System utilizing the river channel. If sufficient funds were made available in the interest of navigation, it would be desirable and advantageous to combine improvement of navigation and conveyance of water in one system of works extending from the delta to Mendota.

15. The initial State Water Plan in the Great Central Valley could not be financed from direct revenues which could be anticipated from the sale of water and electric energy on a basis of financing at an interest rate of $4\frac{1}{2}$ per cent per annum and amortization of the capital investment in 40 years.

16. Many interests, not only local but also State and National, would be benefited substantially through the consummation of the initial State Water Plan in the Great Central Valley. The furnishing of adequate water supplies for the maintenance of production on the present developed lands in the upper San Joaquin Valley, Sacramento Valley and Sacramento-San Joaquin Delta would prevent a loss of taxable wealth, help to restore agricultural credit, maintain and increase business in communities of the affected areas and between those areas and the large metropolitan centers, and assist in the protection of public utility and banking investments in these areas. Similar benefits would accrue from furnishing of adequate water supplies to the industrial areas in the upper San Francisco Bay region. Industrial and commercial business would be benefited not only within the State but in interstate trade as well. Reduction of floods on the Sacramento and San Joaquin rivers would provide an additional degree of flood protection and decrease potential flood damages. Improvement of navigation on the Sacramento and San Joaquin rivers would effect material savings in transportation costs on commodities moving to and from the Sacramento and San Joaquin valleys. The value of the foregoing benefits would more than offset the portion of the cost not capable of being met by anticipated direct revenues from sale of water and electric energy.

17. With the financial assistance of the Federal Government which would be justified and might be reasonably anticipated, in the form of direct contributions and loans at a low interest rate or without interest, in conformity with established policies and precedents for financial participation in such projects for improvement of navigation, flood control, irrigation and hydroelectric power development, and with contributions from the State Government in accord with its interest therein, the direct revenues anticipated from the sale of water and electric energy under the operation of the initial State Water Plan for the Great Central Valley would be sufficient in amount to meet all annual carrying charges comprising interest, amortization, depreciation, operation and maintenance, and the initial project would be self-supporting and self-liquidating.

CHAPTER II

WATER SUPPLY

The water supply of the San Joaquin River Basin, as set forth in this report and considered available for use, is the run-off from the mountain and foothill areas only. Contributions to surface run-off and ground water from precipitation on the valley floor, although of considerable importance in some localities in the basin, have not been included in the available water supply because of the lack of definite knowledge as to the amounts.

Description of Basin.

The San Joaquin River Basin occupies that portion of the State lying between the Sierra Nevada on the east, the Coast Range on the west, the San Emigdio and Tchachapi mountains on the south and the San Joaquin, Mokelumne and Cosumnes rivers on the north. The basin is approximately 290 miles long and 130 miles wide and embraces an area of 32,000 square miles, 20.6 per cent of the total area of the State. It contains within its exterior boundaries 36.3 per cent of the agricultural land of the State, the largest percentage of the seven basins into which the State has been divided. The water supply, on the other hand, is only 16.8 per cent of the State's total, exceeded in amount by each of the supplies of the North Pacific and Sacramento River basins. The relations of the San Joaquin River Basin to the remainder of the State in area, in extent of agricultural land and in water production are shown on the frontispiece, "Geographical Distribution of Water Resources and Agricultural Lands in California."

The San Joaquin River Basin is drained by the San Joaquin River and its many tributaries. This stream system, for the purpose of this investigation, has been grouped into 35 divisions, of which there are 13 major streams and 22 minor streams and stream groups. The major streams, all of which head in the Sierra Nevada on the east side of the basin, are from north to south—the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, San Joaquin, Kings, Kaweah, Tule and Kern rivers. The minor streams and stream groups named in geographical order from the most northerly on the west side of the valley to the most southerly and thence northerly on the east side of the valley are Orestimba Creek, Panoche Creek, Cantua Creek, Los Gatos Creek, Tejon Creek, Caliente Creek, Poso Creek, Deer Creek, Yokohl Creek, Limekiln Creek, Dry Creek, Cottonwood Creek, Daulton Creek, Dutchman Creek, Mariposa Creek, Owens Creek, Bear Creek, Burns Creek, Wildcat Creek, Littlejohns Creek, Martells Creek and Sutter Creek.

Most of the major streams of the San Joaquin River Basin drain a rugged mountainous area ranging in elevation from a few hundred feet above sea level, in the foothills, to from 10,000 to nearly 15,000 feet above sea level at the crest of the Sierra Nevada. Some of the

CHAPTER II

WATER SUPPLY

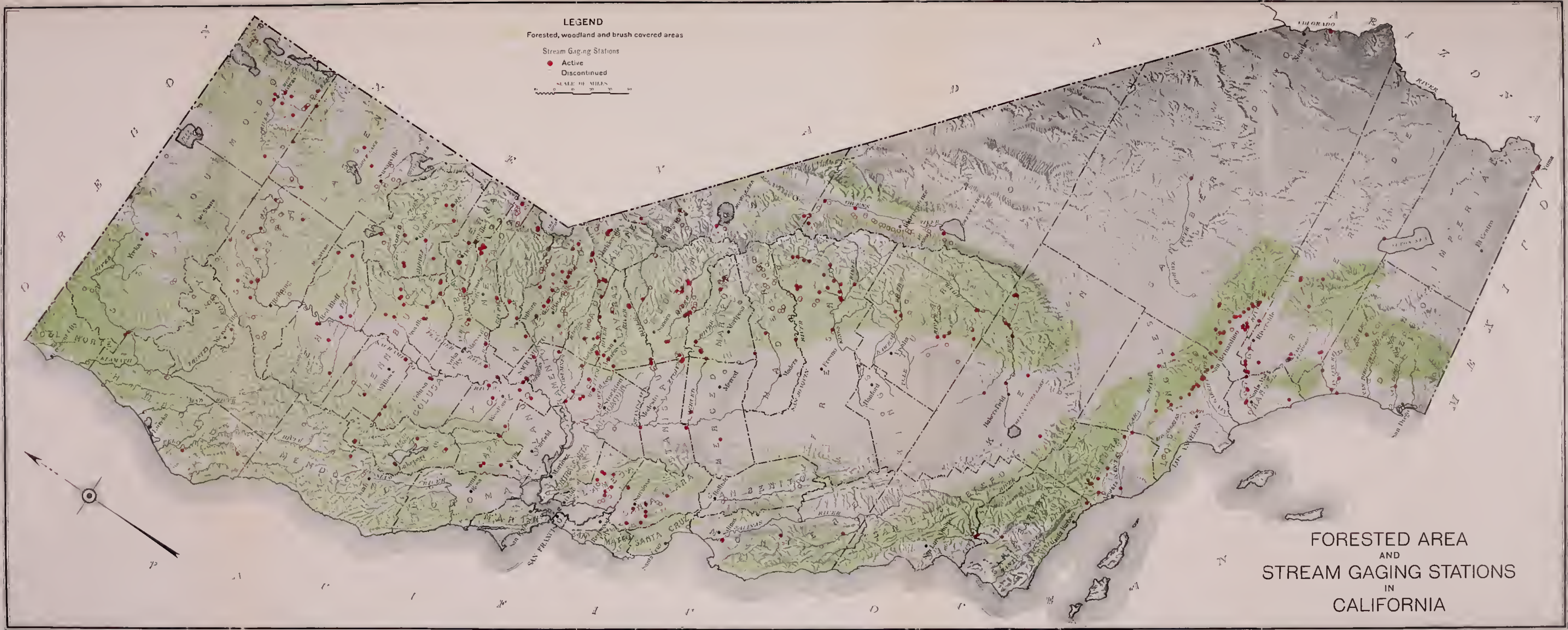
The water supply of the San Joaquin River Basin, as set forth in this report and considered available for use, is the run-off from the mountain and foothill areas only. Contributions to surface run-off and ground water from precipitation on the valley floor, although of considerable importance in some localities in the basin, have not been included in the available water supply because of the lack of definite knowledge as to the amounts.

Description of Basin.

The San Joaquin River Basin occupies that portion of the State lying between the Sierra Nevada on the east, the Coast Range on the west, the San Emigdio and Tehachapi mountains on the south and the San Joaquin, Mokelumne and Cosumnes rivers on the north. The basin is approximately 290 miles long and 130 miles wide and embraces an area of 32,000 square miles, 20.6 per cent of the total area of the State. It contains within its exterior boundaries 36.3 per cent of the agricultural land of the State, the largest percentage of the seven basins into which the State has been divided. The water supply, on the other hand, is only 16.8 per cent of the State's total, exceeded in amount by each of the supplies of the North Pacific and Sacramento River basins. The relations of the San Joaquin River Basin to the remainder of the State in area, in extent of agricultural land and in water production are shown on the frontispiece, "Geographical Distribution of Water Resources and Agricultural Lands in California."

The San Joaquin River Basin is drained by the San Joaquin River and its many tributaries. This stream system, for the purpose of this investigation, has been grouped into 35 divisions, of which there are 13 major streams and 22 minor streams and stream groups. The major streams, all of which head in the Sierra Nevada on the east side of the basin, are from north to south—the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, San Joaquin, Kings, Kaweah, Tule and Kern rivers. The minor streams and stream groups named in geographical order from the most northerly on the west side of the valley to the most southerly and thence northerly on the east side of the valley are Orestimba Creek, Panoche Creek, Cantua Creek, Los Gatos Creek, Tejon Creek, Caliente Creek, Poso Creek, Deer Creek, Yokohl Creek, Limekiln Creek, Dry Creek, Cottonwood Creek, Daulton Creek, Dutchman Creek, Mariposa Creek, Owens Creek, Bear Creek, Burns Creek, Wildcat Creek, Littlejohns Creek, Martells Creek and Sutter Creek.

Most of the major streams of the San Joaquin River Basin drain a rugged mountainous area ranging in elevation from a few hundred feet above sea level, in the foothills, to from 10,000 to nearly 15,000 feet above sea level at the crest of the Sierra Nevada. Some of the


LEGEND
Forested, woodland and brush covered areas
Stream Gaging Stations
Active
Discontinued
SCALE OF MILES
FORESTED AREA
AND
STREAM GAGING STATIONS
IN
CALIFORNIA

80997

major streams, however, have drainage areas which do not reach to the crest of the Sierra Nevada. These streams are the Cosumnes, Calaveras, Chowchilla and Fresno rivers.

The drainage areas of the 22 minor streams and stream groups are situated in general at lower elevations than those of the major streams. Although the drainage basins of Tejon, Caliente, Poso and Deer creeks reach comparatively high elevations, the greater part of each area is located in the foothills adjacent to the valley floor. The minor streams in the lower San Joaquin Valley,* with the exception of Dry Creek in the Sutter Creek group, are not considered as contributing waters utilizable under the general plan of conservation, as their run-off is comparatively small and subject to wide seasonal variations. The estimated run-offs from some of the minor streams on the east side of the upper San Joaquin Valley were considered in computing the inflow to ground water units.

The mountain and foothill areas of the basin total 19,000 square miles. Large portions of these areas are covered with a timber growth. These timbered areas are shown on Plate I, "Forested Areas and Stream Gaging Stations in California."

The main San Joaquin River rises on the western slope of the Sierra Nevada at elevations in excess of 10,000 feet, flows southwesterly until it debouches from the foothills onto the valley floor, thence westerly to a point midway on the valley floor, where it turns northwesterly and traverses the main valley to its confluence with Sacramento River at the head of Suisun Bay. The watershed, above the valley floor, which drains a large area on the western slope of the Sierra Nevada in Fresno and Madera counties, is bounded on the north by that of the Merced and Fresno rivers and on the south by that of the Kings River. It extends eastward to the crest of the Sierra at elevations greater than 13,000 feet at Mt. Lyell and Mt. Goddard and reaches the valley floor about fifteen miles northerly from Fresno at an elevation of 300 feet. The watershed is extremely rugged in character and the formation of the higher portion is largely granitic. The upper reaches of the river have several large branches, the two principal ones being the Middle and South forks, each of which has its source in the glacial lakes near the summit of the range. Below their confluence they form the main channel of the San Joaquin, a narrow and deep canyon with steep sides until it begins to emerge from the foothills. The North Fork rises on the southern slope of Iron Mountain and flows in a nearly due south direction to its junction with the main stream. Several smaller tributaries join the main river between the South and North forks, Stevenson, Big Rock, Chiquito and Kaiser creeks being the more important. Much of the basin below the timber line is forest covered. As the elevation of the head waters of the river is over 10,000 feet, it is snow-fed throughout a large part of the summer.

The Cosumnes River, the most northerly of the San Joaquin River tributaries, drains a secondary watershed on the western slope of the Sierra Nevada just south of the American River. The headwaters

* In this report, the terms "upper" and "lower" San Joaquin Valley are used to designate southerly and northerly divisions of the valley lying respectively south and north of the Chowchilla River on the east side and a line extending from Mendota to Oro Loma on the west side.

originate at an altitude of 7700 feet near Alder Hill, a minor peak about fifteen miles west of the main divide, and the stream follows a southwesterly course to its junction with the Mokelumne River in the San Joaquin River delta region about six miles west of Galt. The total length of the watershed is about 70 miles, the lower half of which stretches across the valley plain and contributes very little to the run-off of the stream. The length of the basin within the main mountain drainage area is about 35 miles with an extreme width of about eighteen miles.

The Mokelumne River drains an area on the western slope of the Sierra Nevada in Amador, Alpine and Calaveras counties. The headwaters rise in the numerous glacial lakes near the crest of the main divide at an elevation of about 10,000 feet. Round Top, the highest peak on the eastern boundary, reaches an elevation of 10,430 feet. The drainage basin is long and narrow extending from the crest of the Sierra in a southwesterly direction for a distance of 140 miles to its junction with the San Joaquin River about twenty miles northwest of Stockton. The mountain area is well forested except in the east end of the basin, which is above the timber line and characterized by bare granite peaks. Over much of the basin the precipitation in winter is entirely in the form of snow, but elevations even in the highest part of the catchment area are not sufficient to support perpetual snow fields. The stream flow is well maintained in the early summer, but rapidly falls off during July and August after the snow has gone. The main stream is formed by the junction of its three principal branches—North, Middle and South forks—which unite some five miles above Electra at an elevation of about 1500 feet. The North Fork is the principal tributary. Below this point, the drainage basin is only four or five miles wide and the main stream follows its canyon for about 35 miles until it emerges from the foothills to the valley floor near the town of Clements at an elevation of 100 feet. It then runs westerly across the valley for 30 miles, passing the towns of Lockeford, Lodi and Woodbridge and joining the San Joaquin River near Central Landing. The Cosumnes River and Dry Creek join the Mokelumne River in the San Joaquin delta region before it discharges into the San Joaquin River.

The Calaveras River drains a secondary watershed on the lower western slope of the Sierra Nevada situated between the basin of the Mokelumne River on the north and that of the Stanislaus River on the south. It rises at an elevation of 5100 feet at the extreme eastern boundary of the watershed about 35 miles west of the main divide of the Sierra Nevada. The two main forks, North and South, join about two miles west of the town of San Andreas to form the main river which flows in a southwesterly direction and joins the San Joaquin River a few miles west of Stockton. The original channel passes to the north of Bellota, 15 miles northeast of Stockton, and extends northwesterly for about nine miles, then turns and runs in a southwesterly direction passing to the north of Stockton before entering the San Joaquin River.

Mormon Slough, which branches from the Calaveras River just east of Bellota, is now considered the main channel of the river. The slough stream bed at this point is several feet lower than the old river and only flood waters now enter the original channel. Mormon Slough flows in a southwesterly direction passing through Stockton and joins the San Joaquin River about one and one-half miles south of the mouth of the original channel. In 1908–10, the Stockton diverting canal was constructed by the United States Government, connecting Mormon Slough with the original channel. This canal, four and one-half miles long, was built for the purpose of diverting a portion of the flood waters of Mormon Slough to the east of Stockton back into the Calaveras River.

The extreme length of the Calaveras watershed from the mouth of the river to its eastern boundary is 67 miles, while the greatest width is 20 miles. The lower foothills are covered with a rather sparse growth of oak and brush. At the higher altitudes there is a heavy growth of timber. Most of the precipitation on the watershed occurs in the form of rainfall. The snowfall is generally light and lies on the ground only for short periods. The watershed above Jenny Lind is favorable for high concentration of discharge as demonstrated by the flood of January 31, 1911, which yielded an average run-off for that day of 177 second-feet per square mile. The flow of the Calaveras River is extremely flashy in nature, with floods of short duration, immediately following heavy rainstorms and lasting from one to three days only.

The Stanislaus River drains a narrow basin on the western slope of the Sierra Nevada between the watersheds of the Calaveras and Mokelumne rivers on the north and that of the Tuolumne River on the south. The watershed area has a length of approximately 100 miles and an average width of ten miles in the lower half. It spreads out above the junction of its forks to a width of 24 miles at its eastern border along the Sierra crest. The main stream is formed by the junction of North, Middle and South forks at an elevation of about 950 feet, seven miles north of Sonora, from which point it meanders in a southwesterly direction a distance of 35 miles through the foothills and thence 25 miles across the valley floor to its junction with the San Joaquin River about three miles northeast of Vernalis. The watershed slopes from an elevation of over 10,000 feet at the crest of the Sierra Nevada to an elevation of about 20 feet at the San Joaquin River. The upper reaches of the basin are characterized by bare granite peaks and precipitous canyons. At lower elevations the ridges and valleys are well covered with timber which gradually gives way to scattering oak and brush as the foothill region is reached.

The watershed of the Tuolumne River drains an area on the western slope of the Sierra Nevada lying between the basin of the Stanislaus River on the north and that of the Merced River on the south. The stream has its source in the glacial lakes on the northern slope of Mount Lyell and flows in a southwesterly direction for a distance of about 150 miles to its junction with the San Joaquin River 10 miles west of Modesto. The upper portion of the drainage basin is characterized by plateaus and meadows, but the stream soon drops into a deep canyon cut in the granite formation by glacial action, and follows this gorge for a distance of 80 miles, finally emerging from the foothills onto the San Joaquin Valley floor near the town of La Grange. Elevations of the watershed range from 300 feet at the mouth of the canyon near La Grange to over 13,000 feet along the crest of the Sierra divide which separates the Tuolumne Basin from the Mono Lake and Walker River watersheds to the east. These higher elevations are for the most part granite peaks, but at lower elevations the mountains and valleys are well timbered with several varieties of pine. The foothills are fairly well covered with scrub oak and brush. The principal tributaries of the Tuolumne River enter from the north, and in an upstream order are: Woods Creek, North Fork of Tuolumne River, Clavey River, Cherry, Falls, Rancheria and Return creeks. The South Fork of Tuolumne River with its tributary, the Middle Fork, enters the main stream from the south at about elevation 1800 feet.

The Merced River rises at an elevation of about 11,000 feet in the Cathedral and Ritter ranges west of the head waters of the Tuolumne and San Joaquin rivers in the Sierra Nevada. Elevations in the watershed vary from about 400 feet at the Exchequer Dam to 13,090 feet at the summit of Mt. Lyell. The main river flows for a distance of 135 miles almost in a due westerly direction from its source to its junction with the San Joaquin River, four miles northeast of Newman. After it passes through Yosemite Valley at an elevation of about 4000 feet, it is joined by the South Fork which rises in the vicinity of Merced Peak. The drainage basin, lying wholly within Mariposa and Merced counties, is very rugged at the head waters, but is more regular below Yosemite Valley. It has a length of about 65 miles from the crest of the ridge to the valley floor and an average width of 20 to 25 miles.

The Chowchilla River drains a secondary watershed on the lower western slope of the Sierra Nevada, lying between the basin of the Merced River on the north and that of the Fresno River on the east and south. It rises at an elevation of about 6000 feet, 50 miles westerly from the crest of the Sierra Nevada, and flows in a southwesterly direction to the valley floor. The channel divides after reaching the plains and water enters the San Joaquin River only at high flow stages. The drainage basin is situated in Mariposa and Madera counties. The upper part of the basin is fairly well forested, and the lower part is covered with scattering trees and brush. The stream rises at a point too far from the crest of the Sierra and at too low an elevation to be snow fed in the summer months, resulting in a run-off varying from little or no flow to flashy floods.

The Fresno River, like the Chowchilla, drains a secondary watershed of the lower western slope of the Sierra Nevada lying between the Merced River watershed on the north and the San Joaquin River watershed on the south. The watershed has the same general characteristics as that of the Chowchilla River. The Fresno River rises at an elevation of about 7000 feet, 40 miles westerly from the crest of the Sierra Nevada, and flows in a southwesterly direction to the valley floor, thence westerly to its junction with the San Joaquin River northeasterly from Dos Palos. The upper portion of the watershed consists of several branches which come together to form a single channel at Windy Gap. From this point the stream remains in a well defined rock-bound channel for several miles with no tributaries of importance until its junction with Coarse Gold Creek. On the lower reaches the streambed of Fresno River broadens to a wide sandy channel. The stream rises at a point in the Sierra Nevada at an elevation too low to be snow fed in the summer months and the natural run-off varies from little or no flow in late summer to flashy floods during the rainy season.

The Kings River drains a large area on the western slope of the Sierra Nevada in Fresno and Tulare counties. The watershed is situated between the San Joaquin River Basin on the north and that of the Kaweah and Kern River basins on the south. The main stream is formed well up in the mountains by the confluence of the North, Middle and South forks. These branches head in the numerous glacial lakes spread along the crest of the Sierra Nevada, between Mount Goddard, elevation 13,555 feet, on the north and nearly to Mount Whitney on the south, which rises to an elevation of 14,501 feet above sea level, the highest peak in the United States. Above elevation 10,000 feet the drainage basin is very rugged, consisting mainly of granite left bare by glacial action, but below this elevation the mountains are well timbered. The main canyon of the river extends southwesterly to a point in the foothills about ten miles northeast of Sanger. Here the river emerges from the foothills to the valley floor, where it has built up a large delta. Most of the discharge reaching the lower part of the delta passes northwesterly through Fresno Slough to the San Joaquin River about two miles north of Mendota. In times of high flood, however, a portion of the discharge flows southerly to Tulare Lake. The watershed has characteristics very similar to that of the San Joaquin River. As nearly 400 square miles of the basin are above elevation 10,000 feet, it is snow fed during a large part of the year. The basin, above the valley floor, has a length of about 50 miles and an average width of about 30 miles.

The Kaweah River drains a watershed on the western slope of the Sierra Nevada in Tulare County, adjoining that of the Kings River on the north and the Tule River on the south and extending on the east to a secondary ridge, parallel to the main backbone of the Sierra Nevada, called the Great Western Divide, which separates its basin from that of the upper Kern River. The headwaters rise in glacial lakes along the divide near Triple Divide Peak, elevation 12,651 feet. The main stream is formed about ten miles above the head of its delta, by the confluence of the North, Middle and South forks. Below the foothills it divides into several distributaries, which cross the delta fan and enter Tulare Lake near Corcoran. The basin above the lower edge of the foothills is about 26 miles long with an average width of about 20 miles.

The Tule River drains a small and somewhat rectangular area on the lower western slope of the Sierra Nevada lying south of the Kaweah River Basin, west of the Kern River Basin and north of the Deer Creek Basin. The headwaters rise at an elevation of about 9500 feet near Sheep Mountain. The main stream is formed by the junction of the North and Middle forks about ten miles northeast of its point of emergence from the foothills at Porterville. The South Fork joins the main stream six miles east of this point. Flood waters flow westward through old delta channels to Tulare Lake. The north and south length of the basin is about 25 miles and its average width about fifteen miles.

The Kern River is the most southerly of the large streams rising in the Sierra Nevada and discharging into the San Joaquin Valley. Its watershed is situated in Kern and Tulare counties. The basin extends almost due north and south for 90 miles, with a maximum width of about 30 miles. The northern part of the watershed is divided into two drainage basins by a high rugged central ridge that runs nearly due south from the main divide at Cottonwood Pass and terminates north of South Fork Valley just east of Kernville. The western basin is drained by the North Fork and its main tributary, Little Kern, and the eastern basin by the South Fork. The eastern boundary of the basin runs south from Mt. Whitney and is formed by the main backbone of the Sierra Nevada. The western boundary is formed by the Great Western Divide and by its extension, the Greenhorn Mountains. The northern boundary lies on the Kings-Kern Divide and the southern along the terminal ridges of the Sierra Nevada, where they join the Tehachapi Mountains. The main or North Fork of the Kern River heads in the extreme north end of the basin in the Mt. Whitney region and flows southerly for about 80 miles to its junction with the South Fork. The South Fork, which drains the eastern part of the Kern River Basin, flows southward parallel to the eastern boundary and then turns nearly due west to join the main stream. The two parts of the drainage basin differ greatly in topography. The basin of the North Fork is extremely rugged, while that of the South Fork is rather flat and abounds in meadows situated among irregular chains of hills. The two forks join at Isabella to form the main Kern River, which flows in a southwesterly direction through a deep and rugged canyon for about 31 miles, and then emerges abruptly onto the valley floor about twelve miles east of Bakersfield. From this point its course is westerly to Buena Vista Lake.

The rocks of most of the region are granitic, but the granite formation is most noticeable in the barren and arid ridges of the southern part of the basin, and in the glaciated higher peaks. The southern and eastern parts of the basin are sparsely covered with juniper and chaparral, but above Kernville the growth improves generally and at some points the forest cover is excellent. About 47 per cent of the North Fork drainage area lies above elevation 8000 feet whereas 76 per cent of the South Fork lies below that elevation. The effect of this difference in elevation is reflected in the run-off record, for although it drains approximately one-half the total area, the North Fork yields about 75 per cent of the mean seasonal run-off. Altitudes in the Kern River Basin range from a few hundred feet at the mouth of the river's lower canyon to more than 14,000 feet on the headwaters. More than 50 peaks in the basin exceed 13,000 feet in elevation and many of the lakes which feed the upper stream are at an altitude of 11,000 feet or more.

The watershed areas above the lower edge of the foothills for each of the major streams of the San Joaquin River Basin, between various elevations, are set forth in Table 1.

TABLE 1

DISTRIBUTION OF DRAINAGE AREAS OF THE MAJOR STREAMS OF THE SAN JOAQUIN RIVER BASIN ABOVE THE LOWER EDGE OF THE FOOTHILLS BY ZONES OF ELEVATION

River	Area, in square miles				
	Below 2,500 feet	Between 2,500 and 5,000 feet	Between 5,000 and 10,000 feet	Above 10,000 feet	Totals
Cosumnes, above Michigan Bar	238	212	84	0	534
Mokelumne, above Clements	121	194	317	0	632
Calaveras, above Jenny Lind	301	90	3	0	394
Stanislaus, above Knights Ferry	223	205	541	14	983
Tuolumne, above La Grange	248	375	805	115	1,543
Merced, above Merced Falls	191	317	494	52	1,054
Chowchilla, above Buchanan	161	72	5	0	238
Fresno, above edge of foothills	167	89	14	0	270
San Joaquin, above Friant	182	227	925	297	1,631
Kings, above Piedra	283	201	824	386	1,694
Kaweah, above Three Rivers	61	141	275	37	514
Tule, above Porterville	142	117	131	0	390
Kern, above Bakersfield	102	572	1,470	266	2,410

The San Joaquin Valley floor is a comparatively level area except for an isolated group of hills along its southwestern edge called the Kettleman Hills. The valley is about 270 miles long from the mouth of the San Joaquin River to the edge of the foothills south of Bakersfield and averages 50 miles wide. Elevations range from a few feet below sea level in the San Joaquin River Delta to 1500 feet at the edge of the foothills in the southern end of the valley. The area of the valley floor is about 13,000 square miles including the San Joaquin Valley portion of the delta formed at the confluence of the Sacramento and San Joaquin rivers. The main valley floor contains a gross area of agricultural lands of about 11,300 square miles, and the San Joaquin Valley portion of the delta about 436 square miles. The valley floor, by reason of physiographic characteristics, falls naturally into three divisions, the area south of the upper San Joaquin River, the area between the upper San Joaquin River and the delta and the delta region. The delta division comprises the delta proper or the low marsh and peat lands, which in their natural condition were subject to tidal overflow, and the bordering alluvial rim-lands subject to occasional inundation from flood waters. The area between the delta and upper San Joaquin River is divided on the east side of the main river by the major tributary channels. The west side is fairly smooth, except for occasional minor stream channels or draws. Upstream from the mouth of the Merced River, bordering the main San Joaquin River on the west for a width of several miles, is a strip of territory traversed by the winding courses of scores of slough channels, some of which are as large as the main San Joaquin River channel itself, and in time of floods carry the major portion of the stream flow. Immediately south of the San Joaquin River is a natural ridge or barrier formed by the Kings River Delta on the east side of the valley trough, and to a minor extent by deposit from Panoche Creek on the west. In the depression south of this ridge is Tulare Lake which receives the surplus flow of all streams south of Kings River. Part of the surplus Kings River run-off flows north through Fresno Slough to the San Joaquin River and part south to Tulare Lake. In its natural condition Tulare Lake covered an area varying from a few square miles in dry cycles to about 760 square miles in wet ones. Reclamation by levees now restricts the submerged area to smaller tracts under normal run-off conditions. South of Kern River Delta a similar shallow but smaller lake stores surplus flood waters of Kern River. The area of this lake also has been restricted by levees, which cause excess water to drain north to Tulare Lake through an artificially deepened and leveed channel. A delta also has been built up by the Kaweah River immediately south of the Kings River Delta. It does not extend westward a sufficient distance, however, to form a barrier in the valley trough.

Precipitation.

Data on the precipitation in the San Joaquin River Basin have been collected, compiled and published by the United States Weather Bureau and its predecessor, the Army Signal Corps, for about 150 stations for varying periods. Some of the earlier stations established have been discontinued. The longest record available is at Stockton, which has been kept continuously since 1867. A number of these rainfall records date back to the early 70s and are of great value in estimating the probable water yield of the San Joaquin River Basin during the period prior to the commencement of stream flow measurements by the United States Geological Survey.

During a previous investigation* a careful study and analysis were made of precipitation records of the entire State. Inquiry was made into the geographical distribution, magnitude and variation of occurrence, both seasonal and periodic, of precipitation in all sections of the State. An important part of the study was the relation of precipitation in any one season to normal or mean precipitation. From the results of the study the State was divided into 26 precipitation groups or divisions, having similar precipitation characteristics. These are shown by the blue lines on Plate II, "Geographical Distribution of Precipitation in California," and have been identified by letters of the alphabet. Eight of the divisions (K, L, P, Q, R, S, T and V) lie entirely or partly in the San Joaquin River Basin. A list of the precipitation stations in the San Joaquin River Basin, compiled and published by the United States Weather Bureau, and the period of record at each station are set forth in Table 2. In general, the periods of record are continuous between the dates shown. However, there is an occasional month, in which it is believed there was some precipitation, for which records are missing for certain stations. In calculating the number and fractions of years of available records, no deductions were made for these months. The locations of these stations are also shown on Plate II. The solid red dots indicate stations at which records are now being obtained, and open red circles those which have been discontinued.

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works, 1923.

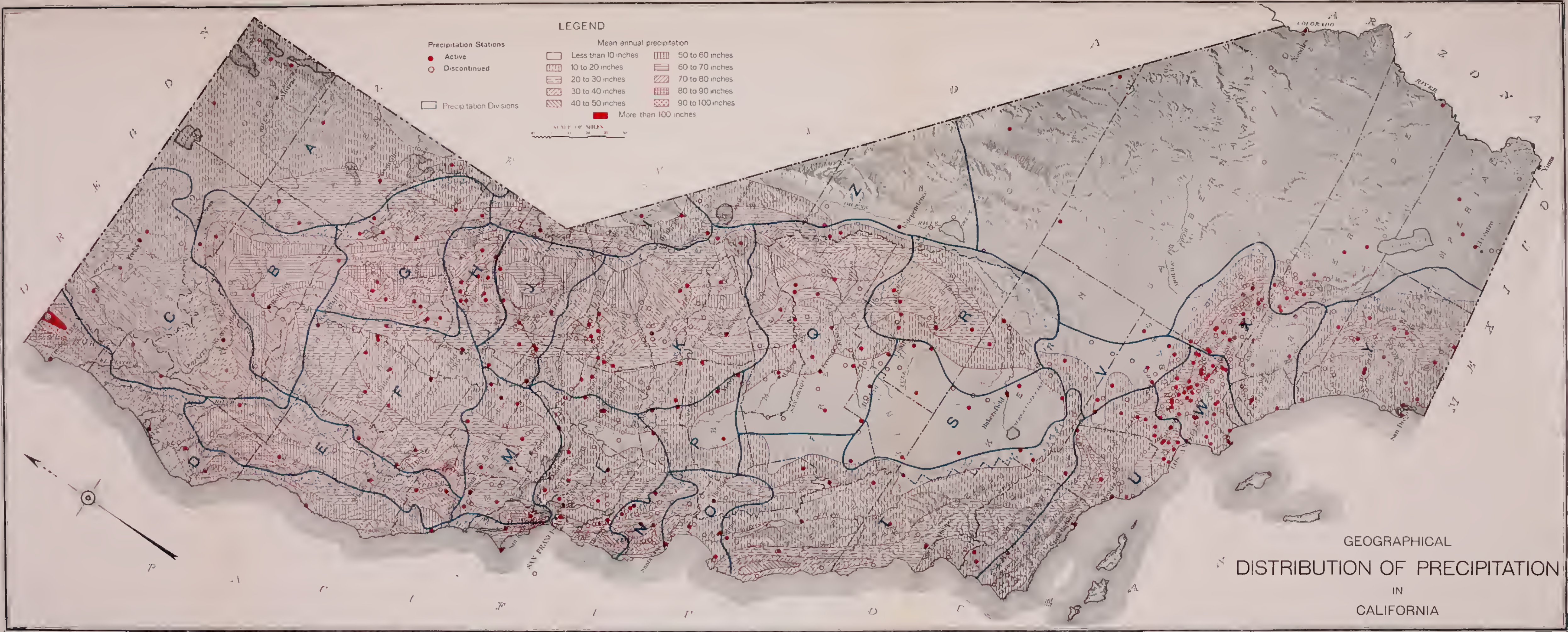
condition Tulare Lake covered an area varying from a few square miles in dry cycles to about 760 square miles in wet ones. Reclamation by levees now restricts the submerged area to smaller tracts under normal run-off conditions. South of Kern River Delta a similar shallow but smaller lake stores surplus flood waters of Kern River. The area of this lake also has been restricted by levees, which cause excess water to drain north to Tulare Lake through an artificially deepened and leveed channel. A delta also has been built up by the Kaweah River immediately south of the Kings River Delta. It does not extend westward a sufficient distance, however, to form a barrier in the valley trough.

Precipitation.

Data on the precipitation in the San Joaquin River Basin have been collected, compiled and published by the United States Weather Bureau and its predecessor, the Army Signal Corps, for about 150 stations for varying periods. Some of the earlier stations established have been discontinued. The longest record available is at Stockton, which has been kept continuously since 1867. A number of these rainfall records date back to the early 70s and are of great value in estimating the probable water yield of the San Joaquin River Basin during the period prior to the commencement of stream flow measurements by the United States Geological Survey.

During a previous investigation * a careful study and analysis were made of precipitation records of the entire State. Inquiry was made into the geographical distribution, magnitude and variation of occurrence, both seasonal and periodic, of precipitation in all sections of the State. An important part of the study was the relation of precipitation in any one season to normal or mean precipitation. From the results of the study the State was divided into 26 precipitation groups or divisions, having similar precipitation characteristics. These are shown by the blue lines on Plate II, "Geographical Distribution of Precipitation in California," and have been identified by letters of the alphabet. Eight of the divisions (K, L, P, Q, R, S, T and V) lie entirely or partly in the San Joaquin River Basin. A list of the precipitation stations in the San Joaquin River Basin, compiled and published by the United States Weather Bureau, and the period of record at each station are set forth in Table 2. In general, the periods of record are continuous between the dates shown. However, there is an occasional month, in which it is believed there was some precipitation, for which records are missing for certain stations. In calculating the number and fractions of years of available records, no deductions were made for these months. The locations of these stations are also shown on Plate II. The solid red dots indicate stations at which records are now being obtained, and open red circles those which have been discontinued.

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works, 1923.



GEOGRAPHICAL
DISTRIBUTION OF PRECIPITATION
IN
CALIFORNIA

TABLE 2

PRECIPITATION STATIONS IN SAN JOAQUIN RIVER BASIN

Records published by U. S. Weather Bureau

Station	Stream Basin	Period of Record	Record available to June 30, 1929, in years
Precipitation Division K—			
Oleta*	Sutter Creek	July, 1891–June, 1902	11
Drytown*	Sutter Creek	Dec., 1891–Sept., 1906	14¾
Ione*	Sutter Creek	Jan., 1878–Dec., 1915	38
Sutter Creek*	Sutter Creek	July, 1887–Jan., 1899	11½
Jackson*	Sutter Creek	Sept., 1877–June, 1886	8¾
Jackson (near)*	Sutter Creek	Nov., 1891–Oct., 1903	12
Kennedy Mine	Sutter Creek	Jan., 1892–June, 1929	37½
Tamarck*	Mokelumne River	Mar., 1900–Aug., 1903 Jan., 1906–June, 1927	25
Bear River*	Mokelumne River	July, 1907–June, 1914	7
Mitchell Mill*	Mokelumne River	Jan., 1915–Sept., 1916	1¾
West Point	Mokelumne River	Jan., 1894–June, 1929	35½
Mill Creek No. 1	Mokelumne River	Jan., 1907–June, 1929	22½
Electra	Mokelumne River	Jan., 1904–June, 1929	25½
Mokelumne Hill*	Mokelumne River	Jan., 1882–June, 1927	45½
Lancha Plana	Mokelumne River	July, 1926–June, 1929	3
Wallace	Bear Creek	July, 1926–June, 1929	3
Valley Springs*	Calaveras River	Jan., 1888–Dec., 1915	28
Jenny Lind	Calaveras River	Jan., 1907–June, 1929	22½
Milton*	Rock Creek	July, 1888–Oct., 1928	40⅓
Calaveras Ranger Station*	Stanislaus River	Jan., 1916–Dec., 1920	5
Angels Camp*	Stanislaus River	Jan., 1908–Nov., 1915	8
Melones*	Stanislaus River	Jan., 1907–June, 1927	20½
American Camp*	Stanislaus River	Jan., 1915–Jan., 1917	2
Penstock Camp*	Stanislaus River	Mar., 1907–Aug., 1910	3½
Long Camp*	Tuolumne River	Jan., 1909–April, 1911	2⅓
Phoenix Dam*	Tuolumne River	Nov., 1908–Dec., 1916	8¼
Sonora	Tuolumne River	Sept., 1887–June, 1929	41¾
Jamestown*	Tuolumne River	Jan., 1903–July, 1915	12½
Jacksonville*	Tuolumne River	Jan., 1907–Dec., 1917	11
Groveland*	Tuolumne River	Jan., 1904–April, 1916	12⅓
La Grange	Tuolumne River	Jan., 1868–June, 1900 Oct., 1908–June, 1929	53¼
Merced Falls	Merced River	Jan., 1907–June, 1929	22½
Dudleys	Merced River	Jan., 1909–June, 1929	20½
Kinsley*	Merced River	Jan., 1915–Nov., 1916	2
Crockers*	Tuolumne River	July, 1896–April, 1910	13¾
Lake Eleanor	Tuolumne River	Nov., 1909–June, 1929	19⅔
Hetch-Hetchy	Tuolumne River	Oct., 1910–June, 1929	18¾
Yosemite	Merced River	Jan., 1904–June, 1929	25½
Glacier Point*	Merced River	Jan., 1920–Oct., 1923	3¾
Summerdale*	Merced River	Jan., 1896–Sept., 1912	16¾
Mariposa	Mariposa Creek	July, 1908–June, 1929	21
Galt*	San Joaquin Valley Floor	Jan., 1878–Dec., 1915	38
Elliot	San Joaquin Valley Floor	July, 1926–June, 1929	3
Clements	San Joaquin Valley Floor	July, 1926–June, 1929	3
Bellota	San Joaquin Valley Floor	Jan., 1911–June, 1929	18½
Farmington*	San Joaquin Valley Floor	Jan., 1877–Dec., 1915	39
Oakdale*	San Joaquin Valley Floor	Oct., 1880–May, 1918	37⅔
Oakdale (near)	San Joaquin Valley Floor	Mar., 1918–June, 1929	11⅓
Denair (Elmwood) (Elmdale)	San Joaquin Valley Floor	Jan., 1899–June, 1929	30½
Precipitation Division L—			
Antioch	San Joaquin Valley Floor	Jan., 1879–June, 1929	50½
Brentwood*	San Joaquin Valley Floor	July, 1890–Dec., 1894 June, 1897–Dec., 1899	7
Byron*	San Joaquin Valley Floor	Feb., 1890–Dec., 1894 June, 1897–Dec., 1905	13⅓
Tracy*	San Joaquin Valley Floor	Jan., 1879–Dec., 1915	37
Lathrop	San Joaquin Valley Floor	July, 1877–Dec., 1894 June, 1897–Nov., 1899 July, 1909–June, 1929	40
Stockton No. 1	San Joaquin Valley Floor	Jan., 1867–June, 1929	62½
Stockton No. 2	San Joaquin Valley Floor	July, 1926–June, 1929	3
Lodi	San Joaquin Valley Floor	Jan., 1888–Sept., 1912 July, 1926–June, 1929	27¾
Rio Vista	San Joaquin Valley Floor	Jan., 1893–June, 1929	36½
Bensons Ferry	San Joaquin Valley Floor	Jan., 1918–June, 1929	11½
Precipitation Division P—			
Modesto	San Joaquin Valley Floor	Jan., 1871–Dec., 1915 July, 1927–June, 1929	47
Westley*	San Joaquin Valley Floor	Jan., 1889–Dec., 1915	27

* Discontinued in U. S. Weather Bureau publications.

TABLE 2—Continued

PRECIPITATION STATIONS IN SAN JOAQUIN RIVER BASIN

Records published by U. S. Weather Bureau

Station	Stream Basin	Period of Record	Record available to June 30, 1929, in years
Precipitation Division P—Continued			
Newman	San Joaquin Valley Floor	Jan., 1889–June, 1929	40½
Turlock	San Joaquin Valley Floor	Jan., 1879–Dec., 1899 Aug., 1920–June, 1929	30
Livingston*	San Joaquin Valley Floor	Nov., 1885–Sept., 1898 Jan., 1921–Nov., 1922	14¾
Merced	San Joaquin Valley Floor	Jan., 1872–June, 1929	57½
Le Grand	San Joaquin Valley Floor	June, 1899–June, 1929	30
Los Banos	San Joaquin Valley Floor	Jan., 1873–Dec., 1915 Jan., 1926–June, 1929	46½
Orestimba*	San Joaquin Valley Floor	Feb., 1899–May, 1899	⅓
Precipitation Division Q—			
Raymond*	Fresno River	Mar., 1899–Oct., 1900	1⅔
Pollasky*	San Joaquin River	June, 1897–Dec., 1903 Jan., 1907–Dec., 1911	11½
Friant	San Joaquin River	Jan., 1897–Dec., 1903 Jan., 1906–June, 1929	30½
North Fork	San Joaquin River	Mar., 1904–June, 1929	25⅓
Crane Valley	San Joaquin River	July, 1903–June, 1929	26
Huntington Lake	San Joaquin River	July, 1915–June, 1929	14
Big Creek (Cascada)	San Joaquin River	July, 1915–June, 1929	14
Stevenson Creek*	San Joaquin River	April, 1916–Dec., 1917	1¾
Auberry	San Joaquin River	July, 1915–June, 1929	14
Balch Camp	Kings River	July, 1926–June, 1929	3
Dinkey Meadow	Kings River	Nov., 1921–June, 1929	7⅔
Helm Creek (Hobbler's Camp)	Kings River	Jan., 1922–June, 1929	7½
Cliff Camp	Kings River	Nov., 1921–June, 1929	7⅔
Dunlap*	Kings River	Jan., 1912–Dec., 1915	4
Hume*	Kings River	Jan., 1914–Dec., 1915	2
Piedra	Kings River	Jan., 1917–June, 1929	12½
Athlone*	San Joaquin Valley Floor	Dec., 1885–May, 1898	13½
Minturn*	San Joaquin Valley Floor	Jan., 1899–Dec., 1899	1
Firebaugh	San Joaquin Valley Floor	Jan., 1873–June, 1886 Jan., 1907–June, 1929	36
Mendota*	San Joaquin Valley Floor	Jan., 1894–Nov., 1908	15
Berenda*	San Joaquin Valley Floor	Mar., 1889–Dec., 1894 June, 1897–Dec., 1899	7½
Madera (Storey)	San Joaquin Valley Floor	June, 1899–June, 1929	30
Borden*	San Joaquin Valley Floor	May, 1875–Dec., 1895	20⅔
Clovis (near)	San Joaquin Valley Floor	Jan., 1917–June, 1929	12½
Helm	San Joaquin Valley Floor	Dec., 1927–June, 1929	1½
McMullin*	San Joaquin Valley Floor	Jan., 1895–Feb., 1898	3¼
Fresno	San Joaquin Valley Floor	July, 1881–June, 1929	48
Sanger*	San Joaquin Valley Floor	Jan., 1889–Dec., 1915	27
Kings River	San Joaquin Valley Floor	Jan., 1929–June, 1929	½
Reedley*	San Joaquin Valley Floor	Aug., 1899–June, 1923	24
Selma*	San Joaquin Valley Floor	Jan., 1886–Dec., 1915	30
Kingsburg (near)	San Joaquin Valley Floor	July 1879–Dec., 1900 Jan., 1928–June, 1929	23
Dinuba	San Joaquin Valley Floor	June, 1897–Dec., 1899 Jan., 1909–June, 1929	23
Huron*	San Joaquin Valley Floor	Oct., 1891–Oct., 1905	14
Lemoore*	San Joaquin Valley Floor	July, 1879–Dec., 1901	22½
Goshen*	San Joaquin Valley Floor	July, 1887–Oct., 1902	15⅓
Traver*	San Joaquin Valley Floor	Dec., 1885–Dec., 1894 Aug., 1897–Dec., 1899	11½
Westhaven	San Joaquin Valley Floor	Jan., 1926–June, 1929	3½
Hanford	San Joaquin Valley Floor	June, 1899–June, 1929	30
Visalia	San Joaquin Valley Floor	July, 1877–June, 1886 Jan., 1888–June, 1929	50½
Precipitation Division R—			
Lemoncove	Kaweah River	Jan., 1899–June, 1929	30½
Lime Kiln*	Kaweah River	June, 1898–Oct., 1898	½
Three Rivers	Kaweah River	July, 1909–June, 1929	20
Ash Mountain	Kaweah River	July, 1926–June, 1929	3
Giant Forest	Kaweah River	July, 1921–June, 1929	8
Milo*	Tule River	April, 1898–May, 1922	24¼
Springville (near)	Tule River	Oct., 1907–June, 1929	21¾
Hot Springs	Deer Creek	Jan., 1907–June, 1929	22½
Glenville (near)	Poso Creek	July, 1909–June, 1929	20
Weldon*	Kern River	Jan., 1904–Dec., 1906	3
Kernville	Kern River	Jan., 1894–June, 1929	35½

* Discontinued in U. S Weather Bureau publications.

TABLE 2—Continued

PRECIPITATION STATIONS IN SAN JOAQUIN RIVER BASIN

Records published by U. S. Weather Bureau

Station	Stream Basin	Period of Record	Record available to June 30, 1929, in years
Precipitation Division R—Continued			
Isabella*	Kern River	Feb., 1896–June, 1910	14½
Mt. Breckenridge*	Kern River	Jan., 1897–Aug., 1897	⅔
Caliente*	Caliente Creek	Jan., 1876–Dec., 1915	40
Delano*	San Joaquin Valley Floor	Jan., 1876–Dec., 1908	33
Precipitation Division S—			
Exeter*	San Joaquin Valley Floor	Mar., 1892–Dec., 1899	7¾
Lindsay	San Joaquin Valley Floor	July, 1914–June, 1929	15
Porterville	San Joaquin Valley Floor	Jan., 1889–June, 1929	40½
Tulare*	San Joaquin Valley Floor	Mar., 1874–Dec., 1914	40¾
Tulare (near)*	San Joaquin Valley Floor	Jan., 1893–Oct., 1909	16¾
Angiola	San Joaquin Valley Floor	July, 1899–June, 1929	30
Wasco	San Joaquin Valley Floor	July, 1899–June, 1929	30
Famosa*	San Joaquin Valley Floor	Jan., 1897–Aug., 1897	⅔
Bakersfield	San Joaquin Valley Floor	Jan., 1889–June, 1929	40½
Calloway Canal*	San Joaquin Valley Floor	Jan., 1895–Feb., 1899	4¼
Edison (near)	San Joaquin Valley Floor	Jan., 1904–June, 1929	25½
Bear Valley No. 1*	Sycamore Canyon	Jan., 1897–Jan., 1916	19
Precipitation Division T—			
Coalinga	San Joaquin Valley Floor	Jan., 1912–June, 1929	17½
Alcalde*	San Joaquin Valley Floor	Aug., 1888–July, 1893	5
Antelope Valley	San Joaquin Valley Floor	July, 1911–June, 1929	18
Idria	Panoche Creek	Jan., 1918–June, 1929	11½
Dudley	San Joaquin Valley Floor	Jan., 1912–June, 1929	17½
Middlewater	San Joaquin Valley Floor	July, 1911–June, 1929	18
Maricopa	San Joaquin Valley Floor	July, 1911–June, 1929	18
Pattiway	Bitter Creek	Dec., 1915–June, 1929	13½
Fort Tejon*	Grape Vine Creek	Feb., 1895–Dec., 1901	7
Precipitation Division V—			
Keene*	Caliente Creek	July, 1879–June, 1902 Jan., 1906–Dec., 1912	30
Girard*	Caliente Creek	Jan., 1889–Dec., 1894 Jan., 1897–Dec., 1899	9
Tehachapi	Caliente Creek	Dec., 1876–Dec., 1915 July, 1926–June, 1929	42
Tejon Ranch	Tejon Creek	Jan., 1894–May, 1896 July, 1898–Dec., 1906 April, 1909–June, 1929	31¼

*Discontinued in U. S. Weather Bureau publications.

In the previous investigation the precipitation in a particular season at a station was expressed by a number representing the precipitation in per cent of normal and defined as the "index of seasonal wetness." The indices for each division were calculated from precipitation records at stations within the division. For stations with missing records, indices were estimated from records at other stations within the same or adjacent divisions. The index for each season in a particular division was taken as the arithmetical mean of the indices of seasonal wetness of the several stations in that division. Indices were calculated for the 26 precipitation divisions for the period 1871 to 1921.

Precipitation division "K" embraces the western slope of the Sierra Nevada and the eastern portion of the San Joaquin Valley floor adjacent thereto, from the drainage basin of Cosumnes River on the north to that of the Chowchilla River on the south and that portion of the eastern slope of the Sierra draining into Mono Lake. Precipitation division "L" includes that part of the San Francisco Bay drainage basin in Alameda, San Mateo and Contra Costa counties, the drainage basins of the small streams on the west side of the San Joaquin River Basin and the western part of the valley floor in Contra Costa, Alameda, San Joaquin and the northern portion of Stanislaus counties. Precipitation division "P" includes the drainage basins of the small streams on the west side of the valley and the western portion of the valley floor in the southern part of Stanislaus and the northern part of Merced counties. Precipitation division "Q" covers the drainage basins of the streams draining the western slope of the Sierra Nevada from the Daulton Creek Group on the north to the Kings River on the south, the eastern part of the valley floor adjacent thereto and the northern portion of the Owens River drainage basin on the eastern slope of the Sierra Nevada. Precipitation division "R" includes the western slope of the Sierra Nevada from the drainage basin of the Kaweah River on the north to that of Kern River on the south and the southern portion of the Owens River drainage basin on the eastern slope of the Sierra Nevada. Precipitation division "S" contains the southern portion of the San Joaquin Valley floor lying in Kings, Tulare and Kern counties. Precipitation division "T" includes the drainage basins of the minor streams on the western side of the San Joaquin Valley from Panoche Creek on the north to Muddy Creek on the south. Precipitation division "V" covers the northern slope of the Tehachapi Mountains and contains the drainage basins of the minor streams from Caliente Creek on the east to San Emigdio Creek on the west.

In the present investigation, the indices of seasonal wetness for the precipitation divisions of the San Joaquin River Basin were calculated for the seasons 1921–1929, by the same method used in the previous investigation. The normal for the period, 1871–1921, was used for each station in making the extensions. In precipitation division "V" the rainfall records at all stations used in Bulletin No. 5 were discontinued. This made the substitution of additional stations necessary and indices were recomputed for the 50-year period. In division "T" the addition of several new stations within the San Joaquin River Basin made the recomputation of the indices advisable. The indices of seasonal wetness for precipitation divisions in the San Joaquin River Basin for the period 1871–1929 are shown in Table 3. These indices are useful not only in showing the variation of precipitation by seasons during the 58-year period, but also in estimating the run-off from unmeasured streams and measured streams with missing records.

A review of the data on indices of seasonal wetness in Table 3 shows that there is a wide variation in precipitation from season to season at any particular station and also that there are wet and dry periods which have occurred throughout the basin. The period from 1916 to 1929 was one of low precipitation. The precipitation in a majority of the seasons in that period was less than normal. The variation in mean seasonal precipitation throughout the State is delineated on Plate II. On this plate, each type of shading represents areas having a mean seasonal precipitation within the limits set forth in the legend.

6—80997

TABLE 3

INDICES OF SEASONAL WETNESS FOR SAN JOAQUIN RIVER BASIN

Season	Index of wetness in division							
	K	L	P	Q	R	S	T*	V*
1871-72	122	130	119	119	120	119	79	79
1872-73	86	79	91	74	75	74	56	56
1873-74	87	86	87	100	101	100	84	84
1874-75	61	69	83	64	64	64	82	96
1875-76	154	131	123	124	125	124	138	124
1876-77	34	43	30	60	53	43	28	36
1877-78	112	129	108	109	140	100	137	155
1878-79	78	79	59	41	25	36	65	42
1879-80	105	99	98	134	137	90	123	139
1880-81	87	107	94	122	96	118	80	93
1881-82	85	69	65	69	83	56	80	78
1882-83	88	87	92	85	88	72	81	92
1883-84	135	125	158	178	181	138	189	184
1884-85	67	66	71	78	71	66	66	78
1885-86	129	115	133	169	123	110	146	110
1886-87	68	70	50	88	86	72	75	77
1887-88	64	78	59	67	60	74	100	85
1888-89	74	98	74	92	78	89	119	97
1889-90	174	192	178	153	119	130	192	122
1890-91	86	86	80	79	87	83	91	105
1891-92	90	91	93	102	107	96	70	123
1892-93	132	139	130	101	94	95	143	109
1893-94	122	111	81	83	88	58	44	105
1894-95	148	147	137	119	139	122	103	132
1895-96	104	106	100	82	91	81	84	103
1896-97	124	112	111	107	125	114	101	118
1897-98	62	57	48	56	54	62	35	71
1898-99	89	91	73	82	73	81	66	58
1899-00	103	104	106	102	82	104	71	84
1900-01	129	121	134	137	119	127	130	94
1901-02	97	91	86	75	97	96	81	101
1902-03	108	99	100	81	97	78	86	101
1903-04	108	105	73	81	71	78	73	79
1904-05	108	124	135	132	118	147	132	130
1905-06	139	120	144	148	169	189	118	159
1906-07	148	144	160	131	123	131	153	135
1907-08	64	72	74	81	90	109	100	98
1908-09	119	124	114	113	165	142	146	117
1909-10	98	93	99	95	102	104	97	80
1910-11	133	121	125	132	103	117	163	86
1911-12	62	64	65	73	76	85	90	89
1912-13	58	52	48	66	67	79	61	96
1913-14	117	128	152	123	135	131	149	134
1914-15	114	126	145	124	111	174	161	148
1915-16	94	120	136	123	153	121	107	89
1916-17	82	78	83	88	98	107	87	90
1917-18	77	53	94	91	62	80	110	84
1918-19	89	105	100	81	88	109	85	90
1919-20	76	66	82	91	99	106	76	73
1920-21	110	98	120	95	92	119	79	80
1921-22	106	103	129	124	102	144	126	109
1922-23	106	102	109	101	98	97	74	64
1923-24	47	47	49	48	48	63	58	91
1924-25	115	117	110	99	119	112	66	99
1925-26	76	87	92	77	76	82	93	71
1926-27	105	104	100	108	111	129	112	98
1927-28	90	87	83	78	77	98	69	76
1928-29	76	67	85	80	87	91	59	76

* Indices for divisions T and V are computed for and apply particularly to those portions of these divisions lying in the San Joaquin River Basin.

From Plate II it may be seen that there is considerable difference in the values of the mean seasonal precipitation in various portions of the San Joaquin River Basin. The mean seasonal precipitation varies from 50 inches in the mountains at the northern end of the basin to less than 10 inches at the southern end of the San Joaquin Valley floor. In general, the precipitation decreases from north to south and increases with the elevation in the Sierra Nevada up to a maximum at an elevation of about 6000 feet and decreases slightly above this elevation to the crest of the mountains. The precipitation on the eastern slope of the Coast Range Mountains draining toward the San Joaquin River Basin is less than at the same elevation of the western slope of the Sierra Nevada.

Precipitation in the San Joaquin River Basin has large monthly variations. With the exception of occasional summer showers in the mountain areas, practically all of the precipitation occurs during the months of September to May, inclusive. About ninety per cent occurs during the months of November to April, inclusive. There is little or no rainfall on the valley floor between May and September, the period of greatest irrigation demand. The entire seasonal precipitation on the valley floor contributes only a fraction of the water supply required for the consumptive use of the average crops produced in the San Joaquin Valley.

Precipitation on the higher mountain areas occurs in the form of snow during the winter months. This snow packs down, does not melt until late spring or early summer months, and produces the same effect in run-off as though the precipitation had been extended beyond the usual rainy season.

Run-off.

The most reliable knowledge of the run-off of the San Joaquin River Basin is derived from stream flow measurements. The first stream flow records were obtained during the period 1878–1884, under the direction of William Ham. Hall, State Engineer. Measurements and estimates were made of the run-off for the following streams in the San Joaquin River Basin: San Joaquin River at Hamptonville, Kern River at Rio Bravo Ranch, Caliente Creek at base of foothills, Poso Creek at base of foothills, White River at base of foothills, Deer Creek at base of foothills, Tule River at Porterville, Kaweah River at Wutchumna Hill, Kings River at Slate Point, Fresno River at base of foothills, Chowchilla River at base of foothills, Mariposa Creek at base of foothills, Bear Creek at base of foothills, Merced River at Merced Falls, Tuolumne River at Modesto, Stanislaus River at Oakdale, Calaveras River at Bellota, Mokelumne River at Lone Star Mill, Dry Creek at base of foothills and Cosumnes River at Live Oak Suspension Bridge. These activities were discontinued after 1884.

Beginning in the nineties, gaging stations were established on the more important streams in the San Joaquin River Basin by the United States Geological Survey. Since 1903 these stations have been maintained by the Geological Survey in cooperation with the State. The oldest station in the basin for which a continuous record of run-off is available to date is that on the Kern River near Bakersfield, established September 29, 1893 and still maintained by the Kern County Land and Water Company. This gives a continuous 36-year record of run-off from October, 1893, to October, 1929. Other stations were progressively established and at the present time are maintained on all the major streams and many of their tributaries. In 1929, stream flow records were available from 89 of the United States Geological Survey stations. During the 1929–1930 seasons five stations were established or reestablished in the San Joaquin River Basin by that agency. In addition to the records from stations maintained by, or others made available through United States Geological Survey, there are a number from stations maintained by power companies and irrigation districts on streams, canals or reservoirs which are of value, particularly in estimating diversions and use from the various streams. The stations of greatest value in estimating the available water supply of the San Joaquin River Basin are those maintained on the major streams at or near the line where the foothills meet the valley floor. These stations at the foothill line furnish data on the run-off of the mountain and foothill areas which may be made available for use in the valley. The United States Geological Survey gaging stations in the San Joaquin River Basin established prior to September 30, 1929, are shown in Table 4. In the table are given for each station, the name of the stream, location of the gaging station, the tributary drainage area, where known, and the period of stream flow record.

TABLE 4

UNITED STATES GEOLOGICAL SURVEY STREAM GAGING STATIONS IN SAN JOAQUIN RIVER BASIN

Established prior to September 30, 1929

Stream	Station name	Area of drainage basin, in square miles	Period of stream flow record
Kern River	Near Kernville	845	Jan. 1, 1912–Sept. 30, 1929
Kern River and Kern No. 3 Canal	Near Kernville	845	Oct. 1, 1920–Sept. 30, 1929
Kern River	At Kernville		Jan. 1, 1905–Sept. 30, 1912
Kern River	At Isabella	1,220	Oct. 5, 1910–Sept. 30, 1912 Oct. 1, 1925–Sept. 30, 1929
Kern River and Borel Canal	At Isabella		Oct. 1, 1925–Sept. 30, 1929
Kern River	Near Bakersfield	2,410	Sept. 29, 1893–Sept. 30, 1929
Kern River No. 3 Canal	Near Kernville		Mar. 7, 1921–Sept. 30, 1929
Salmon Creek	Near Kernville		Feb. 19, 1922–Sept. 30, 1923
Kern River Power Co.'s Canal	At Kernville		Jan. 1, 1910–Sept. 30. 1914
Borel Canal	At Tilley Creek		Jan. 1, 1910–Sept. 30, 1914 Oct. 1, 1925–Sept. 30, 1929
South Fork of Kern River	Near Onyx		Sept. 12, 1911–Aug. 31, 1914 Jan. 23, 1919–Sept. 30, 1929
South Fork of Kern River	At Isabella		Jan. 1, 1929–Sept. 30, 1929
Erskine Creek	Near Isabella		Feb. 7, 1911–Sept. 30, 1912
Thomas Ditch	Near Onyx		April 11, 1929–Sept. 30, 1929
Lowell Ditch	Near Onyx		April 11, 1929–Sept. 30, 1929
Basin Creek	Near Havilah	36	Feb. 8, 1911–Sept. 30, 1912
Tejon House Creek	At Tejon ranch house	17	Jan. 1, 1895–Nov. 30, 1896
San Emigdio Creek	At San Emigdio ranch house	54	Sept. 1, 1894–Dec. 31, 1895
Poso Creek	Near Bakersfield	247	Mar. 21, 1920–May 26, 1920
White River	Near Hot Springs	33	Jan. 18, 1911–Sept. 30, 1913
Deer Creek	At Hot Springs	11	Oct. 7, 1910–Sept. 30, 1929
Tyler Creek	Near Hot Springs		Jan. 16, 1911–Sept. 30, 1913
North Fork of Middle Fork of Tule River	Near Springville		Jan. 1, 1909–Dec. 31, 1912
Tule River	Near Porterville	264	April 8, 1901–Sept. 30, 1929
S. Fork of Middle Fork of Tule River	Near Springville		Jan. 1, 1909–Dec. 31, 1912
Bear Creek	Near Springville		Jan. 23, 1911–Oct. 25, 1916
South Fork of Tule River	Near Porterville	74	Oct. 10, 1910–Sept. 30, 1929
Kaweah River	Near Three Rivers	514	April 29, 1903–Sept. 30, 1929
Kaweah River	At McKay Pt. near Lemoncove		Oct. 1, 1918–July 7, 1921
North Fork of Kaweah River	At Kaweah		Oct. 12, 1910–Sept. 30, 1929
South Fork of Kaweah River	Near Three Rivers		Sept. 18, 1911–Sept. 30, 1924
Kings River	Near Hume	835	Aug. 28, 1921–Sept. 30, 1929
Kings River	Above North Fork	952	Mar. 16, 1927–Dec. 31, 1928
Kings River	At Piedra (near Sanger)	1,694	Sept. 3, 1895–Sept. 30, 1929
Kings River	At Kingsburg	1,742	May 1, 1896–Dec. 31, 1897
North Fork of Kings River	Below Meadowbrook	35	Oct. 1, 1921–Sept. 30, 1929
North Fork of Kings River	Near Cliff Camp	174	Aug. 25, 1921–Sept. 30, 1929
North Fork of Kings River	Below Rancheria Creek	225	Mar. 8, 1927–Sept. 30, 1929
North Fork of Kings River	Above Dinkey Creek	246	Dec. 26, 1919–Sept. 30, 1929
Helm Creek	At Sand Meadow	34	Oct. 22, 1922–Sept. 30, 1929
Rancheria Creek	Near Smith Meadow	22	Oct. 1, 1924–Sept. 30, 1929
Dinkey Creek	Near Ockenden		Sept. 17, 1910–Sept. 30, 1912
Dinkey Creek	At Dinkey Meadows	51	Oct. 27, 1921–Sept. 30, 1929
Dinkey Creek	At mouth	136	Jan. 7, 1920–Sept. 30, 1929
Deer Creek	Below East Fork	21	Oct. 1, 1923–Sept. 30, 1929
Big Creek	Near Tollhouse		Mar. 21, 1911–Sept. 30, 1913
Tulare Lake	In Kings County		June 6, 1906–Sept. 30, 1920
South Fork of San Joaquin River	Near Florence Lake	171	Dec. 29, 1921–Sept. 30, 1929
South Fork of San Joaquin River	Near Hoffman Meadow	428	Nov. 17, 1921–Sept. 30, 1928
San Joaquin River	Above Big Creek	1,060	Aug. 11, 1912–Sept. 30, 1915 Mar. 25, 1922–Sept. 30, 1929
San Joaquin River	Near North Fork		April 1, 1910–Sept. 30, 1914
San Joaquin River	Near Friant	1,631	Oct. 18, 1907–Sept. 30, 1929
San Joaquin River	At Herndon	1,637	Jan. 1, 1895–Dec. 31, 1901
San Joaquin River	Near Newman		April 29, 1912–Sept. 30, 1929
San Joaquin River	Near Vernalis		July 29, 1922–Sept. 30, 1929
San Joaquin River	At Lathrop		Oct. 1, 1920–July 15, 1922
Florence Lake Tunnel	At intake		April 13, 1925–Sept. 30, 1929
Bear Creek	Near Vermillion Valley	53	Nov. 29, 1921–Sept. 30, 1929
Mono Creek	Near Vermillion Valley	93	Nov. 25, 1921–Sept. 30, 1929
Middle Fork of San Joaquin River	At Miller Bridge	251	Oct. 12, 1921–July 18, 1928
North Fork of San Joaquin River	Below Iron Creek	37	Oct. 1, 1920–July 15, 1928
Iron Creek	At mouth		Oct. 1, 1922–Sept. 30, 1923
West Fork of Granite Creek	Near Timber Knob		Jan. 1, 1922–Sept. 30, 1925
Granite Creek	Near Cattle Mountain	54	Dec. 2, 1921–July 6, 1928
Middle Fork of Granite Creek	Near Cattle Mountain		Feb. 17, 1922–Sept. 30, 1923
East Fork of Granite Creek	Near Cattle Mountain		Jan. 1, 1922–Sept. 30, 1925
Jackass Creek	Near Jackass Meadow	14	Dec. 1, 1921–July 6, 1928

TABLE 4—Continued

UNITED STATES GEOLOGICAL SURVEY STREAM GAGING STATIONS IN SAN JOAQUIN RIVER BASIN

Established prior to September 30, 1929

Stream	Station name	Area of drainage basin, in square miles	Period of stream flow record
Jackass Creek	Near Fullers Meadow		Mar. 1, 1924–Sept. 30, 1925
West Fork of Jackass Creek	Near Fullers Meadow		Mar. 1, 1924–Sept. 30, 1925
Chiquito Creek	Near Mugler Meadows		Mar. 1, 1924–Sept. 30, 1925
Chiquito Creek	Near Arnold Meadow	60	Sept. 12, 1921–July 7, 1928
Big Creek	Below Huntington Lake	79	Jan. 1, 1910–Sept. 30, 1915 June 18, 1925–Sept. 30, 1929
Big Creek at mouth	Near Big Creek	131	May 10, 1923–Sept. 30, 1928
Pitman Creek	At Big Creek	27	Jan. 1, 1910–Sept. 30, 1915 Jan. 26, 1922–Sept. 30, 1928
Pitman Creek	Below Tamarack Creek		Dec. 1, 1927–Sept. 30, 1929
Stevenson Creek	At Shaver	30	Oct. 1, 1916–Sept. 30, 1920 April 9, 1922–Sept. 30, 1928
Fresno Flume and Lumber Co.'s Upper Flume	At Shaver		Nov. 13, 1915–July 7, 1920
Fresno Flume and Lumber Co.'s Lower Flume	At Shaver		Jan. 6, 1916–June 28, 1919
Southern California Edison Co.'s Flume	At Shaver		Feb. 16, 1922–Sept. 5, 1926
North Fork of San Joaquin River	Near North Fork		April 1, 1910–Dec. 31, 1911
South Fork Creek	Near North Fork	38	April 1, 1910–Sept. 30, 1915
South Fork Ditch	Near North Fork		April 3, 1910–Dec. 31, 1910
Crane Valley Reservoir	Near North Fork	55	April 1, 1910–Sept. 30, 1915
Whiskey Creek	Near North Fork	13	April 1, 1910–Sept. 30, 1915
Cascadel Creek	Near North Fork		April 1, 1910–April 30, 1912
Panoche Creek	Near Panoche		Nov. 15, 1922–May 22, 1923
Silver Creek	Near Panoche		Nov. 21, 1922–May 23, 1923
Fresno River	Near Knowles	134	Sept. 16, 1911–Dec. 31, 1913 Nov. 13, 1915–Sept. 30, 1929
Chowchilla River	Near Buchanan reservoir site	238	Oct. 1, 1921–Sept. 30, 1923
Merced River	Above Illilouette Creek	118	Aug. 21, 1915–Dec. 31, 1915
Merced River	At Happy Isles Bridge near Yosemite	181	Aug. 23, 1915–Sept. 30, 1929
Merced River	At Yosemite	236	July 11, 1904–June 27, 1909 Jan. 4, 1912–Sept. 30, 1916
Merced River	At Pohono Bridge nr. Yosemite	322	Nov. 2, 1916–Sept. 30, 1929
Merced River	At Horseshoe Bend		Nov. 17, 1922–Sept. 30, 1929
Merced River	At Exchequer	1,020	Nov. 28, 1915–Sept. 30, 1929
Merced River	Near Merced Falls	1,054	April 6, 1901–Nov. 30, 1913 April 1, 1923–April 20, 1926
Merced River	Near Livingston		April 29, 1912–Sept. 30, 1912 Mar. 18, 1921–Aug. 31, 1921 Mar. 10, 1922–Sept. 30, 1929
Illilouette Creek	Near Yosemite	62	Aug. 21, 1915–Dec. 31, 1915
Tenaya Creek	Near Yosemite	47	July 11, 1904–June 24, 1909 Jan. 5, 1912–Sept. 30, 1929
Yosemite Creek	At Yosemite	43	July 11, 1904–June 27, 1909 Jan. 4, 1912–Sept. 11, 1926
South Fork of Merced River	Near Wawona		Dec. 15, 1910–June 1, 1922
Lake McClure	At Exchequer		April 20, 1926–Sept. 30, 1929
Tuolumne River	At Hetch Hetchy cabin		Oct. 10, 1910–Sept. 30, 1916
Tuolumne River	At Hetch Hetchy Dam Site	459	May 30, 1901–Sept. 30, 1901 Dec. 1, 1910–Aug. 31, 1915
Tuolumne River	Near Hetch Hetchy		Dec. 20, 1914–Sept. 30, 1929
Hetch Hetchy Reservoir	At Hetch Hetchy	459	May 7, 1923–Sept. 30, 1929
Tuolumne River	Near Buck Meadows		Sept. 2, 1907–Mar. 31, 1909 Sept. 3, 1910–Sept. 30, 1929
Tuolumne River	Near Jacksonville		July 31, 1923–Sept. 30, 1929
Don Pedro Reservoir	Near La Grange	1,536	Oct. 1, 1924–Sept. 30, 1929
Tuolumne River	Above La Grange Dam		Mar. 19, 1915–Sept. 30, 1929
Tuolumne River and canals	Near La Grange	1,543	Aug. 29, 1895–Sept. 30, 1917
Tuolumne River	At Modesto		Jan. 1, 1895–Dec. 31, 1896
Falls Creek	Near Hetch Hetchy	45	Nov. 22, 1915–Sept. 30, 1929
Cherry Creek	At Eleanor Trail Crossing	130	May 26, 1901–Sept. 30, 1901
Cherry Creek	Near Hetch Hetchy	114	April 1, 1910–Sept. 30, 1929
Eleanor Creek	At Eleanor Trail Crossing	81	June 1, 1901–Oct. 15, 1901
Eleanor Creek	Near Hetch Hetchy	79	Nov. 20, 1909–Sept. 30, 1929
Lake Eleanor	Near Hetch Hetchy	79	Oct. 1, 1919–Sept. 30, 1929
South Fork of Tuolumne River	At Italian Flat nr. Sequoia		Oct. 1, 1924–Sept. 30, 1929
South Fork of Tuolumne River	At Harden ranch nr. Sequoia		Jan. 11, 1914–Feb. 23, 1918
South Fork of Tuolumne River	Nr. Oakland Recreation Camp		Mar. 19, 1923–Sept. 30, 1929
South Fork of Tuolumne River	Near Buck Meadows		Oct. 1, 1916–Sept. 30, 1921
Golden Rock Ditch	Near Sequoia		Jan. 1, 1914–June, 30, 1915
Middle Fork of Tuolumne River	Near Mather		Oct. 1, 1924–Sept. 30, 1929

TABLE 4—Continued

UNITED STATES GEOLOGICAL SURVEY STREAM GAGING STATIONS IN SAN JOAQUIN RIVER BASIN

Established prior to September 30, 1929

Stream	Station name	Area of drainage basin, in square miles	Period of stream flow record
Middle Fork of Tuolumne River	Near Buck Meadows		Nov. 23, 1916–Sept. 30, 1929
Woods Creek	Near Jacksonville	103	Oct. 1, 1925–Sept. 30, 1929
Sierra San Francisco Power Co.'s Canal	Near La Grange		Jan. 1, 1908–Jan. 25, 1926
Modesto Canal	Near La Grange		April 26, 1903–Sept. 30, 1929
Turlock Canal	Near La Grange		July 1, 1899–Sept. 30, 1929
Middle Fork of Stanislaus River	At Sand Bar Flat, nr. Avery	329	Sept. 1, 1905–Sept. 30, 1929
Stanislaus River	Near Knights Ferry	973	Dec. 18, 1915–Sept. 30, 1929
Stanislaus River	At Knights Ferry	983	May 19, 1903–April 30, 1916
Stanislaus River	At Oakdale	1,051	June 1, 1895–Feb. 16, 1901
Relief Creek	Near Baker Station		Oct. 1, 1910–Sept. 30, 1918
Relief Reservoir	Near Baker Station	28	Oct. 1, 1910–Sept. 30, 1918
North Fork of Stanislaus River	Near Avery	197	July 14, 1914–Sept. 30, 1922 Nov. 10, 1928–Sept. 30, 1929
Utica Gold Mining Co.'s Canal	Near Avery		May 19, 1915–Sept. 30, 1921
South Fork of Stanislaus River	At Strawberry	54	Oct. 21, 1911–Jan. 31, 1917
Oakdale Canal	Near Knights Ferry		May 3, 1914–Sept. 30, 1929
South San Joaquin Canal	Near Knights Ferry		May 1, 1914–Sept. 30, 1929
Stanislaus and San Joaquin Water Co.'s Canal	At Knight's Ferry		Jan. 1, 1899–Dec. 31, 1899 June 11, 1904–Sept. 30, 1912
Calaveras River	At Jenny Lind	394	Jan. 1, 1907–Sept. 30, 1929
Calaveras River	Near Stockton		Oct. 1, 1925–Sept. 30, 1929
South Channel of Littlejohns Creek	At Farmington	193	Oct. 1, 1925–Sept. 30, 1926
Bear Creek	Near Clements	43	Oct. 1, 1926–Sept. 30, 1927
Bear Creek	Near Lockeford	52	Oct. 1, 1926–Sept. 30, 1929
North Fork of Mokelumne River	Above Moore Creek	160	Sept. 23, 1926–Sept. 30, 1929
North Fork of Mokelumne River	Near West Point	270	April 28, 1917–Sept. 30, 1918 Feb. 1, 1924–Sept. 30, 1929
Mokelumne River	At Electra	537	Jan. 1, 1901–Dec. 31, 1901 May 11, 1903–Dec. 31, 1904
Mokelumne River	Near Mokelumne Hill	539	Nov. 11, 1927–Sept. 30, 1929
Mokelumne River	Near Lancha Plana	584	June 23, 1926–Sept. 30, 1929
Pardee Reservoir	Near Valley Springs	575	Mar. 9, 1929–Sept. 30, 1929
Mokelumne River	Near Clements	632	Jan. 1, 1905–Sept. 30, 1929
Mokelumne River	Near Victor		July 21, 1927–Sept. 30, 1929
Mokelumne River	At Woodbridge	648	May 27, 1924–Sept. 30, 1929
Mokelumne River	Near Thornton	690	July 6, 1926–Sept. 30, 1929
Bear River	At Pardoe Camp	33	July 3, 1927–Sept. 30, 1929
Cold Creek	Near Mokelumne Peak	23	July 23, 1927–Sept. 30, 1929
Middle Fork of Mokelumne River	At West Point	69	Oct. 9, 1911–Sept. 30, 1929
South Fork of Mokelumne River	Near Railroad Flat	41	Oct. 23, 1911–Sept. 30, 1929
Licking Fork of Mokelumne River	Near Railroad Flat		Oct. 23, 1911–Sept. 30, 1912 Mar. 24, 1915–Dec. 17, 1917
Woodbridge Canal	At Woodbridge		April 28, 1926–Sept. 30, 1929
Dry Creek	Near Ione	273	Oct. 7, 1911–June 30, 1912 Dec. 20, 1925–Sept. 30, 1929
Dry Creek	Near Galt	346	Dec. 4, 1926–Sept. 30, 1929
Sutter Creek	Near Volcano		Feb. 12, 1924–Sept. 30, 1927
Sutter Creek	At Sutter Creek	54	Feb. 5, 1922–Sept. 30, 1929
Goose Creek	Near Elliot	8	Jan. 10, 1927–Sept. 30, 1929
North Fork of Cosumnes River	Near Pleasant Valley	158	Feb. 27, 1906–Sept. 1, 1906 Feb. 1, 1924–May 31, 1924
North Fork of Cosumnes River	Near El Dorado	197	Aug. 13, 1911–Sept. 30, 1929
Cosumnes River	At Michigan Bar	534	Oct. 20, 1907–Sept. 30, 1929
Camp Creek	Near Sly Park		Nov. 1, 1923–Nov. 1, 1924
Camp Creek	Near Pleasant Valley		Feb. 1, 1924–May 31, 1924
Sly Park Creek	At Park		Mar. 2, 1906–June 30, 1906

The locations of these stream gaging stations are shown on Plate I, "Forested Area and Stream Gaging Stations in California." On this Plate the solid red dots indicate stations at which records were being taken on September 30, 1929, and the open red circles those stations which had been discontinued.

Data from the United States Geological Survey stations and from stations maintained by other agencies were used in water supply studies for this report.

Full Natural Run-off. The full natural or unimpaired run-off of a stream above any station is the run-off as it would have been if unaltered by diversions, storage development or importation of water from other watersheds. It is the run-off that would have occurred under natural conditions. In these studies the determination of the full natural run-off of each stream was made before attempting any estimates of impaired run-off.

The full natural run-off was calculated for each month from the measured run-off by adding upstream diversions and quantities stored in reservoirs and subtracting importations and reservoir releases. The corrections for storage were made as far as possible from records of actual reservoir operation. Where records were not available and water was known to have been stored, the amounts stored or released were estimated either from records of actual operation in other seasons or from records of operation of other reservoirs on the same watershed, taking into account the difference between the run-off in the season having record and the season being estimated.

The foregoing method of computing the full natural run-off applies only to streams and to periods for which records of measured run-off were available. For streams and periods for which no run-off records were available, one of two methods of estimating the full natural run-off was used. The first involved utilization of the index of wetness (seasonal or monthly), and the development of a relation of run-off to index of wetness for the particular stream. The second consisted in establishing a run-off relation between adjacent streams of parallel record. During periods, for which there were no run-off records on the stream under consideration, the full natural run-off of an adjacent stream was used in estimating the discharge, providing the relation during the period of parallel record showed that more accurate results could be obtained by this method than by the use of the index of wetness.

In using the second method, the full natural monthly run-off of the stream in question was plotted against the corresponding full natural monthly run-off of the adjacent stream having parallel record, and curves were drawn through the mean of the plotted points for each month. By entering these curves with the full natural monthly run-off of the adjacent stream, during periods of missing record on the stream being considered, the required estimate of monthly run-off was obtained.

When it was necessary to use the first, or index of wetness method, in estimating the full natural run-off, either the seasonal full natural run-off computed from available records was plotted against the index of seasonal wetness or the monthly index of wetness was plotted against the monthly full natural run-off computed from the available records

Stream or stream group
Upper San Joaquin Basin—
Panoche Creek
Cantua Creek Group ([a])
Los Gatos Creek
Tejon Creek Group ([b])
Caliente Creek
Kern River
Poso Creek Group ([c])
Deer Creek
Tule River
Yokohl Creek Group ([d])
Kaweah River
Lime Kiln Creek Group ([e])
Kings River
Dry Creek
San Joaquin River
Cottonwood Creek
Fresno River
Daulton Creek Group ([f])
Chowchilla River
Totals, Upper San Joaqu
Lower San Joaquin
Orestimba Creek
Dutchman Creek
Mariposa Creek
Owens Creek Gro
Bear Creek
Burns Creek Gro
Merced River
Tuolumne River
Wildcat Creek G
Stanislaus River
Totals, Lo
Delta Tributaries
Littlejohns Cr
Martells Cree
Calaveras Riv
Mokelumne R
Sutter Creek
Cosumnes Ri
Totals,
Gra

([a]) Cant
Canoas Cree
Creek, Santi
River, Poso
Creek, Greas
Romero Cree
Creek, Bushy
Creek Group
Martells Cre

80997-

The locations of these stream gaging stations are shown on Plate I, "Forested Area and Stream Gaging Stations in California." On this Plate the solid red dots indicate stations at which records were being taken on September 30, 1929, and the open red circles those stations which had been discontinued.

Data from the United States Geological Survey stations and from stations maintained by other agencies were used in water supply studies for this report.

Full Natural Run-off. The full natural or unimpaired run-off of a stream above any station is the run-off as it would have been if unaltered by diversions, storage development or importation of water from other watersheds. It is the run-off that would have occurred under natural conditions. In these studies the determination of the full natural run-off of each stream was made before attempting any estimates of impaired run-off.

The full natural run-off was calculated for each month from the measured run-off by adding upstream diversions and quantities stored in reservoirs and subtracting importations and reservoir releases. The corrections for storage were made as far as possible from records of actual reservoir operation. Where records were not available and water was known to have been stored, the amounts stored or released were estimated either from records of actual operation in other seasons or from records of operation of other reservoirs on the same watershed, taking into account the difference between the run-off in the season having record and the season being estimated.

The foregoing method of computing the full natural run-off applies only to streams and to periods for which records of measured run-off were available. For streams and periods for which no run-off records were available, one of two methods of estimating the full natural run-off was used. The first involved utilization of the index of wetness (seasonal or monthly), and the development of a relation of run-off to index of wetness for the particular stream. The second consisted in establishing a run-off relation between adjacent streams of parallel record. During periods, for which there were no run-off records on the stream under consideration, the full natural run-off of an adjacent stream was used in estimating the discharge, providing the relation during the period of parallel record showed that more accurate results could be obtained by this method than by the use of the index of wetness.

In using the second method, the full natural monthly run-off of the stream in question was plotted against the corresponding full natural monthly run-off of the adjacent stream having parallel record, and curves were drawn through the mean of the plotted points for each month. By entering these curves with the full natural monthly run-off of the adjacent stream, during periods of missing record on the stream being considered, the required estimate of monthly run-off was obtained.

When it was necessary to use the first, or index of wetness method, in estimating the full natural run-off, either the seasonal full natural run-off computed from available records was plotted against the index of seasonal wetness or the monthly index of wetness was plotted against the monthly full natural run-off computed from the available records

TABLE 5

SEASONAL FULL NATURAL RUN-OFFS OF SAN JOAQUIN RIVER BASIN STREAMS

Run-off, in acre-feet

Stream or stream group	Drainage area, in square miles	1889–90	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99	1899–00
Upper San Joaquin Basin—												
Panoche Creek	295	105,500	17,300	6,300	56,700	0	25,200	12,600	23,600	0	4,700	6,300
Cantua Creek Group (a)	208	54,400	7,800	2,200	27,700	0	12,200	5,500	11,100	0	2,200	2,200
Los Gatos Creek	119	41,300	5,700	1,900	20,300	0	8,900	4,400	8,300	0	1,900	2,500
Tejon Creek Group (b)	1,341	306,100	82,000	68,100	164,600	35,700	118,800	59,400	102,300	5,500	8,800	26,900
Caliente Creek	471	60,300	55,300	[illegible]0,300	45,200	40,200	70,400	40,200	57,800	12,600	2,500	20,100
Kern River	2,410	925,000	540,000	7[illegible]8,000	617,000	579,800	1,030,200	637,900	896,000	299,500	342,500	330,900
Poso Creek Group (c)	576	66,000	24,600	[illegible]6,100	30,700	26,100	99,800	29,200	75,300	0	12,300	20,000
Deer Creek	110	27,000	12,900	21,200	15,300	13,500	38,200	14,700	30,600	4,100	8,800	11,200
Tule River	390	163,000	97,000	130,000	109,500	127,700	221,500	119,800	177,200	51,700	49,800	44,700
Yokohl Creek Group (d)	98	20,400	7,800	14,600	9,900	7,800	31,300	8,900	23,500	0	3,700	6,300
Kaweah River	514	1,100,000	509,000	648,000	607,000	399,000	733,000	401,500	471,200	224,400	291,500	311,500
Lime Kiln Creek Group (e)	201	83,500	38,500	65,300	48,200	40,700	116,700	43,900	93,200	8,600	24,600	[illegible]4,300
Kings River	1,694	4,250,000	2,222,000	2,740,000	2,593,000	1,770,000	3,042,000	1,853,700	2,086,200	830,600	1,223,700	1,285,300
Dry Creek	48	12,700	[illegible],500	3,800	3,800	2,000	6,400	1,800	4,600	500	1,800	3,800
San Joaquin River	1,631	4,620,000	2,355,000	2,933,000	2,768,000	1,864,000	2,789,900	1,985,700	2,219,700	922,300	1,269,500	1,343,600
Cottonwood Creek	28	7,000	[illegible]	2,000	1,800	900	3,300	800	2,300	200	800	2,000
Fresno River	270	168,500	31,800	63,600	62,000	36,600	95,400	35,000	71,500	11,100	35,000	63,600
Daulton Creek Group (f)	66	15,900	1,400	4,200	4,200	1,800	7,400	1,800	5,100	400	1,800	4,200
Chowchilla River	238	195,100	44,700	49,700	111,800	94,400	142,900	68,300	99,400	19,900	48,500	67,100
Totals, Upper San Joaquin Basin	10,708	12,221,700	6,055,100	7,618,300	7,296,700	5,040,200	8,593,500	5,325,100	6,458,900	2,441,400	3,334,400	3,586,500
Lower San Joaquin Basin—												
Orestimba Creek Group (g)	1,340	450,200	42,900	71,500	207,200	64,300	235,800	100,000	128,600	0	35,700	107,200
Dutchman Creek Group (h)	72	31,500	4,200	5,000	15,700	12,300	21,500	7,700	13,400	800	4,600	7,700
Mariposa Creek	103	48,200	7,100	7,700	23,000	18,600	31,800	12,100	19,700	2,260	7,700	12,100
Owens Creek Group (i)	66	27,900	2,800	3,500	12,400	9,500	17,700	6,000	10,200	700	3,500	5,600
Bear Creek	71	29,700	3,400	4,600	14,100	11,000	19,800	6,900	11,800	1,100	4,200	6,500
Burns Creek Group (j)	171	80,200	13,700	16,400	43,800	36,500	57,400	24,600	38,300	2,700	15,500	23,700
Merced River	1,054	2,745,000	870,000	963,000	1,625,000	1,535,000	2,378,000	804,500	1,300,200	491,600	688,200	815,400
Tuolumne River	1,543	5,009,000	1,543,000	1,650,000	3,036,000	2,624,000	3,795,000	1,588,200	2,437,100	960,400	1,334,600	1,628,300
Wildcat Creek Group (k)	59	32,900	4,700	5,300	16,300	13,100	22,200	8,500	14,100	900	5,300	8,100
Stanislaus River	983	3,230,000	1,107,000	1,227,000	2,075,000	1,967,000	2,682,400	1,391,200	1,419,800	406,300	828,000	944,200
Totals, Lower San Joaquin Basin	5,462	11,774,600	3,598,800	3,954,000	7,068,500	6,291,300	9,261,600	3,949,700	5,393,200	1,866,700	2,927,300	3,558,800
Delta Tributaries—												
Littlejohns Creek	41	28,700	4,800	5,400	14,000	11,400	19,000	7,800	12,100	2,200	5,200	7,600
Martells Creek Group (l)	122	44,900	8,500	9,800	25,400	21,500	32,500	14,300	22,100	2,600	9,800	14,300
Calaveras River	394	448,400	110,000	93,800	301,200	254,200	470,300	194,300	339,100	44,100	218,500	91,600
Mokelumne River	632	2,062,900	520,300	740,000	1,276,800	942,600	1,446,400	628,300	1,038,000	388,100	547,800	678,800
Sutter Creek Group (m)	285	277,000	57,800	65,500	161,300	137,000	204,000	94,400	141,600	19,800	63,900	92,800
Cosumnes River	534	1,150,900	201,500	312,600	659,500	453,200	820,500	248,100	639,500	173,300	217,100	281,700
Totals, Delta tributaries	2,008	4,012,800	902,900	1,227,100	2,438,200	1,819,900	2,992,700	1,187,200	2,192,400	630,100	1,062,300	1,166,800
Grand totals	18,178	28,009,100	10,556,800	12,799,400	16,803,400	13,151,400	20,847,800	10,462,000	14,044,500	4,938,200	7,324,000	8,312,100

Stream or stream group	1900–01	1901–02	1902–03	1903–04	1904–05	1905–06	1906–07	1907–08	1908–09	1909–10	1910–11
Upper San Joaquin Basin—											
Panoche Creek	45,600	11,000	14,200	7,900	47,200	37,800	66,100	23,600	58,200	22,000	75,500
Cantua Creek Group (a)	23,300	4,400	5,500	3,300	23,300	17,700	33,300	11,100	30,000	8,900	38,800
Los Gatos Creek	16,500	3,800	4,400	2,500	17,100	13,300	24,100	8,300	21,600	7,600	26,700
Tejon Creek Group (b)	123,400	46,700	56,600	26,900	163,500	178,200	218,500	76,000	183,300	57,800	192,800
Caliente Creek	27,600	30,200	37,700	20,100	65,300	105,500	72,900	35,200	55,300	20,100	25,100
Kern River	883,800	580,500	569,500	481,000	559,700	1,848,800	1,065,200	479,500	1,771,500	751,200	1,013,700
Poso Creek Group (c)	66,000	35,300	35,300	10,700	64,500	158,200	72,200	27,600	149,000	41,500	43,000
Deer Creek	27,000	16,500	16,500	8,200	27,000	58,200	30,000	14,100	55,200	18,800	18,200
Tule River	161,100	149,700	146,800	92,100	97,200	481,500	210,000	107,400	397,800	157,500	149,700
Yokohl Creek Group (d)	20,400	11,500	11,500	3,700	20,400	49,600	22,500	8,400	47,000	13,100	13,600
Kaweah River	731,700	355,100	403,900	345,700	337,700	1,088,400	593,500	252,600	799,900	409,200	546,000
Lime Kiln Creek Group (e)	83,500	52,500	52,500	22,500	83,500	173,500	91,000	42,800	166,000	58,900	61,000
Kings River	3,142,500	1,553,000	1,687,800	1,743,300	1,427,800	3,856,700	2,752,500	1,033,900	2,809,400	1,779,000	2,826,700
Dry Creek	9,400	1,300	1,800	1,800	8,400	11,700	8,400	1,800	5,600	3,000	8,400
San Joaquin River	3,004,500	1,633,000	1,768,800	1,821,900	1,512,600	4,039,700	2,900,900	1,161,200	2,904,300	2,041,500	3,587,600
Cottonwood Creek	5,000	500	800	800	4,600	6,400	4,400	800	2,700	1,500	4,600
Fresno River	131,900	27,000	33,400	33,400	120,800	155,800	117,600	33,400	84,200	52,400	120,800
Daulton Creek Group (f)	11,700	1,100	1,400	1,400	10,300	14,900	10,300	1,400	6,400	3,200	10,300
Chowchilla River	106,900	58,400	74,600	74,600	74,600	124,300	142,900	22,400	90,700	59,600	114,300
Totals, Upper San Joaquin Basin	8,621,800	4,571,500	4,923,000	4,701,800	4,665,500	12,420,200	8,436,300	3,341,500	9,638,100	5,506,800	8,876,800
Lower San Joaquin Basin—											
Orestimba Creek Group (g)	200,100	57,200	92,900	42,900	207,200	235,800	314,500	28,600	142,900	85,800	171,500
Dutchman Creek Group (h)	14,600	6,500	8,800	8,800	8,800	18,000	21,500	1,200	11,500	6,900	16,100
Mariposa Creek	21,900	9,900	13,700	13,700	13,700	26,800	31,800	2,200	18,100	9,900	23,600
Owens Creek Group (i)	11,700	4,600	6,400	6,400	6,400	14,500	17,700	1,100	8,800	4,600	13,100
Bear Creek	13,300	5,300	8,000	8,000	8,000	16,400	19,800	1,100	10,700	5,700	14,500
Burns Creek Group (j)	41,900	20,100	27,300	27,300	27,300	50,100	57,400	3,600	34,600	21,000	45,600
Merced River	1,554,000	826,200	979,700	1,093,400	897,700	2,035,100	2,125,800	517,900	1,475,400	1,065,900	2,114,600
Tuolumne River	2,717,800	1,606,000	1,973,000	2,661,300	1,720,000	3,525,400	3,755,700	1,073,600	2,646,900	2,078,100	3,413,400
Wildcat Creek Group (k)	15,700	6,900	9,400	9,400	9,400	19,100	22,200	1,300	12,500	7,200	16,900
Stanislaus River	1,686,400	959,800	1,123,700	2,046,900	975,700	2,414,500	2,834,400	620,000	1,925,900	1,405,800	2,356,900
Totals, Lower San Joaquin Basin	6,277,400	3,502,500	4,242,900	5,918,100	3,874,200	8,355,700	9,200,800	2,250,600	6,287,300	4,690,900	8,186,200
Delta Tributaries—											
Littlejohns Creek	13,200	6,500	8,600	8,600	8,600	16,200	19,000	2,200	11,000	6,700	14,500
Martells Creek Group (l)	24,100	11,700	15,600	15,600	15,600	28,600	32,500	2,600	20,200	12,400	26,000
Calaveras River	234,100	134,800	235,100	377,800	135,700	427,800	707,800	72,700	391,900	194,800	674,700
Mokelumne River	1,120,000	657,300	824,100	1,337,500	660,200	1,370,100	1,692,000	485,700	1,167,500	920,900	1,530,700
Sutter Creek Group (m)	155,300	79,100	103,500	103,500	103,500	175,300	204,000	22,800	129,400	82,200	164,400
Cosumnes River	593,800	255,500	372,700	524,100	279,000	580,600	816,000	150,500	639,000	462,900	876,400
Totals, Delta tributaries	2,140,500	1,144,900	1,559,600	2,367,100	1,202,600	2,598,600	3,471,300	736,500	2,359,000	1,679,900	3,286,700
Grand totals	17,039,700	9,218,900	10,725,500	12,987,000	9,742,300	23,374,500	21,108,400	6,328,600	18,284,400	11,877,600	20,349,700

(a) Cantua Creek Group—Domengine Creek, Martinez Creek, Salt Creek, Cantua Creek, Arroyo Honda, Arroyo Cierva; (b) Tejon Creek Group—Waltham Creek, Jacalitos Creek, Zapato Creek, Canoas Creek, Garza Creek, Avenal Creek, Franciscan Creek, Parkwood Creek, Bitterwater Creek, Devilwater Creek, Media Agua, Santos Creek, Chico Martinez, Salt Creek, Buena Vista Creek, Bitter Creek, Santiago Creek, Muddy Creek, San Amigdio Creek, Pleito Creek, Tecuya Creek, Grapevine Creek, Pastoria Creek, Tunis Creek, El Paso Creek, Tejon Creek; (c) Poso Creek Group—White River, Poso Creek, Rag Gulch; (d) Yokohl Creek Group—Horse Creek, Lewis Creek, Yokohl Creek; (e) Limekiln Creek Group—Limekiln Creek, Rattlesnake Creek, Stokes Creek, Sand Creek, Watoke Creek, Greasy Creek; (f) Daulton Creek Group—Daulton Creek, Dry Creek; (g) Orestimba Creek Group—Little Panoche Creek, Laguna Seca, Ortigalita Creek, Los Banos Creek, San Luis Creek, Romero Creek, Quinto Creek, Mustang Creek, Garzos Creek, Crow Creek, Orestimba Creek, Little Salada Creek, Puerto Creek, Ingram Creek, Hospital Creek, Buenos Aires Creek, Mountain House Creek, Bushy Creek, Kellogg Creek, Marsh Creek, Lone Tree Creek, Sand Creek, Dry Creek, Deer Creek, Salada Creek; (h) Dutchman Creek Group—Dutchman Creek, Deadman Creek; (i) Owens Creek Group—Owens Creek, Miles Creek; (j) Burns Creek Group—Burns Creek, Black Rascal Creek, Fahrens Creek; (k) Wildcat Creek Group—Wildcat Creek, Dry Creek; (l) Martells Creek Group—Martells Creek, Bear Creek, Rock Creek, Big Spring Creek, Peachys Creek; (m) Sutter Creek Group—Dry Creek, Willow Creek, Sutter Creek.

TABLE 5—Continued

SEASONAL FULL NATURAL RUN-OFFS OF SAN JOAQUIN RIVER BASIN STREAMS

Stream or stream group	Drainage area, in square miles	1911-12	1912-13	1913-14	1914-15	1915-16	1916-17	1917-18	1918-19	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29	1889-1929	1909-1929	1919-1920	1924-1929
		Run-off, in acre-feet																		Mean run-off for period, in acre-feet			
Upper San Joaquin Basin																							
Pastoria Creek	[illegible]	17,[illegible]	[illegible]	[illegible]	74,000	[illegible]	[illegible]	[illegible]	14,200	[illegible]	11,000	[illegible]	[illegible]	[illegible]	4,700	[illegible]	[illegible]	6,900	5,100	26,400	31,200	11,000	13,200
Cantua Creek Group (a)	[illegible]	[illegible]	[illegible]	31,800	37,700	[illegible]	[illegible]	[illegible]	5,500	[illegible]	4,400	21,100	[illegible]	1,100	[illegible]	[illegible]	14,100	[illegible]	1,100	12,600	11,300	6,100	5,500
Los Gatos Creek	110	[illegible]	[illegible]	22,800	25,400	10,200	7,100	[illegible]	4,400	[illegible]	3,800	15,200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	600	9,400	8,400	4,800	4,300
Tejon Creek Group (b)	[illegible]	54,[illegible]	[illegible]	[illegible]	257,000	[illegible]	[illegible]	[illegible]	45,600	23,100	[illegible]	131,000	[illegible]	[illegible]	[illegible]	43,800	[illegible]	21,400	[illegible]	88,000	74,700	43,900	41,000
Caliente Creek	[illegible]	35,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27,100	[illegible]	25,100	[illegible]	17,600	42,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15,100	11,100	[illegible]	28,000	21,900	22,100
Kern River	[illegible]	[illegible]	[illegible]	1,10[illegible]	675,[illegible]	[illegible]	[illegible]	520,000	544,100	[illegible]	528,[illegible]	853,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	735,000	691,000	505,000	466,000
Poso Creek Group (c)	[illegible]	15,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41,500	[illegible]	0	[illegible]	[illegible]	[illegible]	15,[illegible]	[illegible]	45,500	[illegible]	32,300	35,300
Deer Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12,[illegible]	17,600	17,[illegible]	[illegible]	[illegible]	5,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16,500	13,400	12,600
Tule River	[illegible]	[illegible]	[illegible]	102,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	145,[illegible]	[illegible]	[illegible]	135,000	113,000	87,200	77,000
Yokohl Creek Group	[illegible]	[illegible]	[illegible]	[illegible]	16,700	[illegible]	11,500	[illegible]	7,800	12,000	[illegible]	11,100	[illegible]	0	[illegible]	[illegible]	11,700	4,700	[illegible]	[illegible]	12,000	10,000	10,900
Kaweah River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	477,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	401,100	[illegible]	101,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	455,000	411,000	391,000
Lime Kiln Creek Group (d)	[illegible]	[illegible]	18,200	110,[illegible]	71,700	[illegible]	[illegible]	[illegible]	40,700	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	71,700	[illegible]	[illegible]	[illegible]	52,[illegible]	16,000	19,700
Kings River	[illegible]	[illegible]	[illegible]	[illegible]	1,817,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,542,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,580,000	[illegible]	1,226,000
Dry Creek	[illegible]	[illegible]	[illegible]	7,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,500	[illegible]	[illegible]	[illegible]	4,100	[illegible]	3,000	2,600
San Joaquin River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	445,[illegible]	1,111,[illegible]	[illegible]	2,000,[illegible]	1,157,500	[illegible]	[illegible]	[illegible]	1,405,000	1,333,000
Cottonwood Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,800	[illegible]	1,200
Fresno River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54,700	[illegible]	[illegible]	14,400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48,000
[illegible] Creek Group	[illegible]	1,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,200	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	1,400	1,400	[illegible]	[illegible]	[illegible]	2,700
Chowchilla River	[illegible]	19,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52,000	[illegible]	70,900	56,200	56,100	55,100
Totals, Upper San Joaquin Basin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,428,800	6,507,[illegible]	[illegible]	1,752,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,688,701
Lower San Joaquin Basin																							
Orestimba Creek Group (e)	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	142,[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	50,000	[illegible]	120,000	[illegible]	87,200	78,600
Dutchman Creek Group (f)	[illegible]	[illegible]	[illegible]	11,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9,200	8,100	8,100	0	[illegible]	[illegible]	8,100	[illegible]	2,700	[illegible]	6,000	5,700	5,000
Mariposa Creek	[illegible]	[illegible]	[illegible]	17,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,400	[illegible]	7,100	[illegible]	[illegible]	9,100	9,000	9,100
Owens Creek Group (g)	[illegible]	[illegible]	400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	1,800	[illegible]	[illegible]	[illegible]	[illegible]	4,500	[illegible]	4,100
Bear Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8,400	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,100	5,200
Burns Creek Group (h)	[illegible]	[illegible]	2,700	[illegible]	[illegible]	[illegible]	11,[illegible]	[illegible]	[illegible]	9,100	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18,800
Merced River	[illegible]	514,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	765,000
Tuolumne River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,344,800	2,020,700	2,474,800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,520,000
Wildcat Creek Group (i)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,100	10,[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	8,500	[illegible]	[illegible]	[illegible]	[illegible]	6,200	6,500
Stanislaus River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	932,000
Totals, Lower San Joaquin Basin	[illegible]	[illegible]	117,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,345,500
Delta Tributaries																							
Littlejohn Creek	[illegible]	[illegible]	1,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,500	[illegible]	[illegible]	[illegible]	8,400	[illegible]	6,000	6,200
Marsh Creek Group (j)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14,500	11,100	10,700	11,100
Calaveras River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115,000
Mokelumne River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	618,000
Sutter Creek Group	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75,900	70,500
Cosumnes River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	289,000	282,000
Totals, Delta Tributaries	[illegible]	[illegible]	[illegible]	2,064,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,102,800
Grand totals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8,546,900	8,137,000

(a) Cantua Creek Group: [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, Arroyo [illegible], Arroyo [illegible]. (b) Tejon Creek Group: [illegible] Creek, [illegible] Creek, Zapato Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, Bitterwater Creek, [illegible] Creek, [illegible] Creek, Buena Vista Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] [illegible] Poso Creek, [illegible]. (d) Yokohl Creek Group: [illegible]. (e) [illegible]. (f) Dutchman Creek Group: [illegible] Creek. (g) Owens Creek Group: Owens Creek, [illegible]. (h) Burns Creek Group: [illegible]. (i) Wildcat Creek Group: Wildcat Creek, Dry Creek. (j) Marsh Creek Group: [illegible] Creek, Bear Creek, [illegible] Creek, [illegible]. (k) Sutter Creek Group: [illegible] Creek.

and curves were drawn through the means of the plotted points. By entering these curves with the proper value of the index of wetness for seasons or months of missing record of run-off, the required estimate of run-off was obtained. The indices of wetness used were those for the precipitation division in which the drainage basin of the stream in question was situated. When the period, during which it was necessary to estimate the full natural run-off from the index of wetness, was of sufficient duration to warrant the refinement, monthly indices of wetness were computed; otherwise seasonal indices of wetness were used.

For minor streams or stream groups where no run-off records were available, estimates of the full natural seasonal run-off were obtained by entering "Probable Run-off Curves" with the proper index of seasonal wetness for the precipitation division in which the stream or stream group is located. These curves, published in another bulletin,* show the relation between index of seasonal wetness and run-off and are based upon records of flow on streams adjacent to the minor streams or stream groups having similar characteristics of flow.

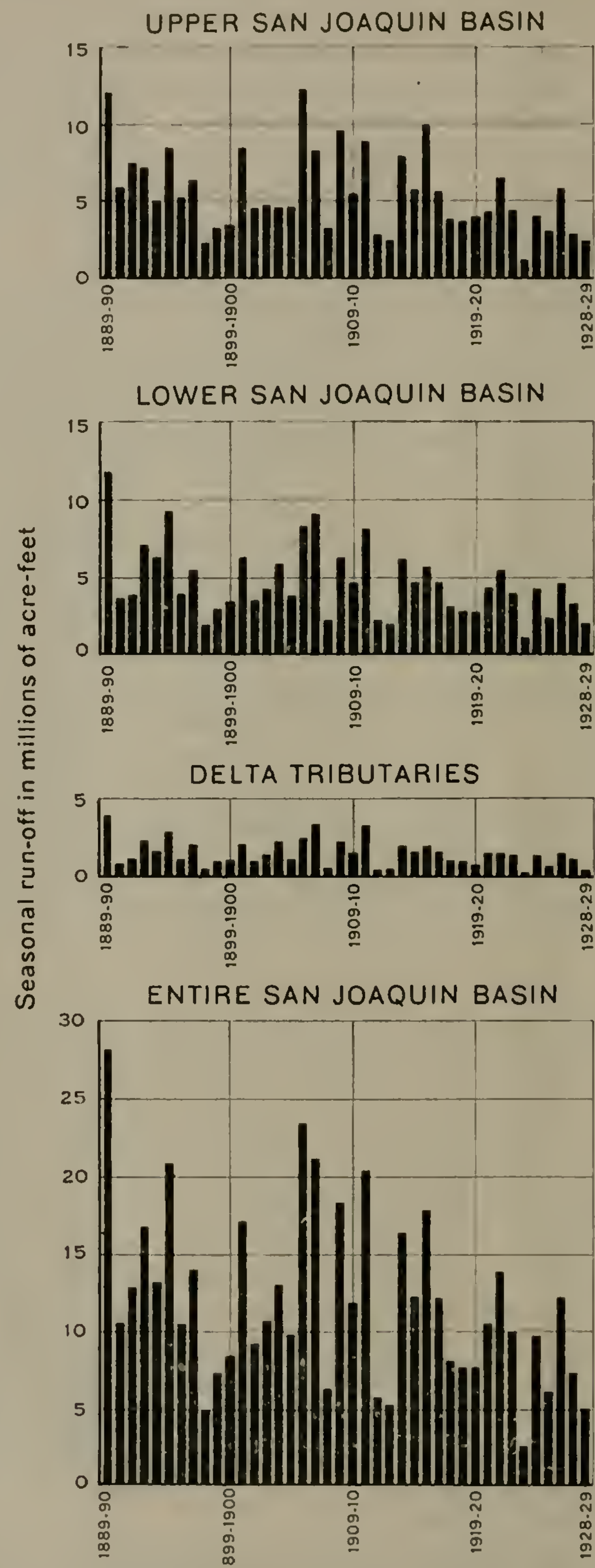
The estimated full natural seasonal run-offs of all streams tributary to the San Joaquin River Basin for the 40-year period, 1889–1929, are shown in Table 5. These estimates show that only about five per cent of the entire run-off from the mountainous area of the San Joaquin River Basin originates in the minor streams or stream groups for which it was necessary to derive run-off estimates entirely by indirect methods. The combined seasonal run-offs of the major streams and minor stream groups tributary to the upper San Joaquin River Basin, lower San Joaquin River Basin and to the delta are shown on Plate III, "Combined Seasonal Run-off of Major Streams and Minor Stream Groups Tributary to San Joaquin River Basin."

Ultimate Net Run-off. The full natural monthly run-off of each major stream at reservoir sites proposed at the edge of the foothills, under the ultimate State water plan, has been adjusted to the run-off anticipated under conditions of ultimate development of the watershed above these points. The ultimate net run-off as used in this report is the natural run-off as modified by diversions and storage development for ultimate irrigation and municipal uses and by present power developments upstream from the main foothill and reservoir sites. Power development and hydraulic mining, while altering the regimen of the stream, do not consume any appreciable amount of water. Therefore, only diversions out of the basin and irrigation use within the basin would materially reduce the full-natural run-off, above the reservoir sites, under conditions of ultimate development. The watersheds of some of the major streams of the San Joaquin River Basin are so mountainous and rugged, however, that no future upstream use for irrigation is considered feasible.

In computing the ultimate net run-off, estimates were made of the total net area to be irrigated by diversion above each of the reservoir sites under conditions of complete development and the amount of water required therefor. Where the natural stream flow was insufficient to furnish adequate irrigation supplies for these areas, it was assumed

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works, 1923.

PLATE III



COMBINED SEASONAL RUN-OFF

OF

MAJOR STREAMS AND MINOR STREAM GROUPS TRIBUTARY TO SAN JOAQUIN RIVER BASIN

ULTIM QUIN RIVER BASIN

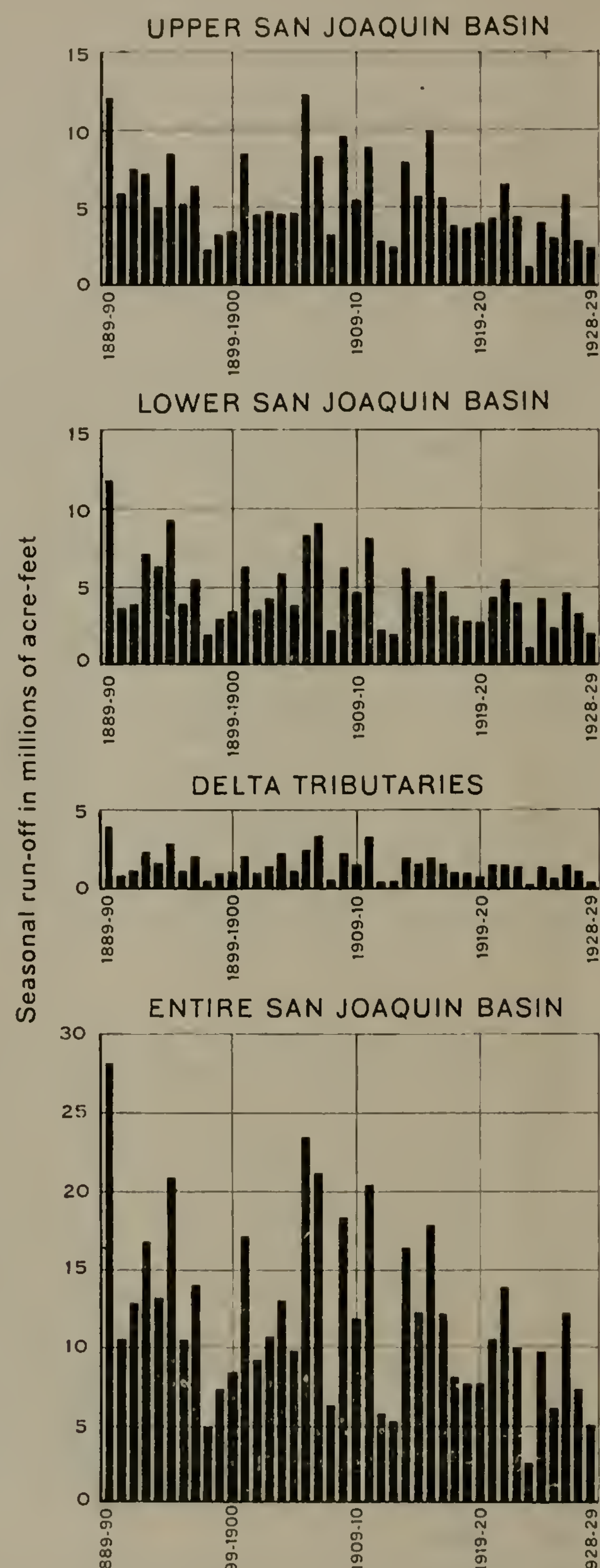
Stream	1889		1900-01	1901-02	1902-03	1900-04
Kern River	91	0	872,100	568,800	557,800	469,300
Tule River[1]	15	0	155,700	145,800	143,400	90,400
Kaweah River	1,10	0	731,700	355,100	403,900	345,700
Kings River	4,25	0	3,142,500	1,553,000	1,687,800	1,743,300
San Joaquin River	4,43	0	2,872,000	1,691,900	1,763,400	1,789,100
Fresno River	15	0	115,800	17,400	26,700	29,700
Chowchilla River	19	0	106,900	58,400	74,600	74,600
Merced River	2,59	0	1,408,400	699,900	834,300	943,700
Tuolumne River	4,03	0	1,899,600	1,352,800	1,443,600	1,737,200
Stanislaus River	3,10	0	1,566,100	855,400	1,016,500	1,929,200
Calaveras River	38	0	175,500	95,300	192,600	334,200
Mokelumne River	2,01	0	1,049,500	647,500	777,900	1,288,200
Cosumnes River	94	0	403,800	151,200	238,600	393,600
Totals	24,26	0	14,499,600	8,192,500	9,161,100	11,168,200

Stream	1904		1915-16	1916-17	1917-18	1918-19
Kern River	54	0	2,462,800	871,800	514,300	532,400
Tule River[1]	9	0	336,400	176,500	51,300	76,300
Kaweah River	33	0	762,200	471,500	229,700	289,200
Kings River	1,42	0	3,041,800	1,892,600	1,363,700	1,203,300
San Joaquin River	1,60	0	2,759,600	1,959,300	1,545,900	1,353,100
Fresno River	10	0	109,100	71,400	40,300	35,300
Chowchilla River	7	0	53,400	39,800	33,600	48,500
Merced River	77	0	1,324,400	991,100	707,500	582,100
Tuolumne River	1,43	0	1,863,400	1,739,000	1,157,200	1,132,600
Stanislaus River	86	0	1,551,900	1,266,000	719,300	668,900
Calaveras River	9	0	304,000	300,300	184,100	69,500
Mokelumne River	6	0	1,004,000	843,700	520,400	568,900
Cosumnes River	16	0	461,800	278,400	134,300	155,600
Totals	8,19	0	16,034,800	10,901,400	7,201,600	6,715,700

Stream		Mean run-off for period, in acre-feet			
		1889-1929	1909-1929	1919-1929	1924-1929
Kern River	0	714,000	679,000	493,000	454,000
Tule River[1]	0	130,000	109,000	84,100	74,500
Kaweah River	0	443,000	355,000	311,000	291,000
Kings River	0	1,889,000	1,580,000	1,321,000	1,226,000
San Joaquin River	0	1,993,000	1,702,000	1,398,000	1,300,000
Fresno River	0	55,200	48,200	39,800	34,000
Chowchilla River	0	70,900	56,200	56,900	55,100
Merced River	0	989,000	825,000	705,000	659,000
Tuolumne River	0	1,634,000	1,393,000	1,240,000	1,230,000
Stanislaus River	0	1,239,000	997,000	839,000	820,000
Calaveras River	0	189,000	156,000	96,400	80,100
Mokelumne River	0	820,000	696,000	597,000	581,000
Cosumnes River	0	290,000	235,000	182,000	169,000
Totals	0	10,456,100	8,831,400	7,363,200	6,973,700

[1] Includes South Fork of Tule River,

PLATE III



COMBINED SEASONAL RUN-OFF
OF
MAJOR STREAMS AND MINOR STREAM GROUPS
TRIBUTARY TO SAN JOAQUIN RIVER BASIN

TABLE 6

ULTIMATE NET SEASONAL RUN-OFF OF MAJOR STREAMS AT RESERVOIR SITES OF STATE PLAN IN SAN JOAQUIN RIVER BASIN

Stream	Run-off, in acre-feet														
	1889–90	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99	1899–00	1900–01	1901–02	1902–03	1900–04
Kern River	913,300	528,300	746,300	605,300	568,100	1,018,500	626,200	884,100	287,800	330,700	319,200	872,100	568,800	557,800	469,300
Tule River[1]	157,800	94,000	125,900	106,100	125,100	212,900	115,900	170,900	50,500	48,500	42,800	155,700	145 800	143,400	90,400
Kaweah River	1,100,000	509,000	648,000	607,000	399,000	733,000	401,500	471,200	224,400	291,500	311,500	731,700	355,100	403,900	345,700
Kings River	4,250,000	2,222,000	2,740,000	2,593,000	1,770,000	3,042,000	1,853,700	2,086,200	880,600	1,223,700	1,285,300	3,142,500	1,553,000	1,687,800	1,743,300
San Joaquin River	4,430,600	2,398,200	2,918,300	2,771,900	1,888,400	2,749,700	2,013,100	2,238,200	1,021,300	1,265,000	1,343,400	2,872,000	1,691,900	1,763,400	1,789,100
Fresno River	151,700	24,400	59,800	53,800	28,900	82,600	27,300	61,100	10,400	33,300	53,000	115,800	17,400	26,700	29,700
Chowchilla River	195,100	44,700	49,700	111,800	94,400	142,900	68,300	99,400	19,900	48,500	67,100	106,900	58,400	74,600	74,600
Merced River	2,593,300	740,600	831,500	1,478,900	1,390,300	2,235,100	672,400	1,183,400	397,200	576,700	709,900	1,408,400	699,900	834,300	943,700
Tuolumne River	4,033,600	1,284,900	1,189,900	2,306,900	2,141,600	3,312,600	1,283,900	1,813,500	931,900	1,065,100	1,461,700	1,899,600	1,352,800	1,443,600	1,737,200
Stanislaus River	3,104,400	999,900	1,114,600	1,960,000	1,854,600	2,559,400	1,292,000	1,302,100	308,100	710,400	834,400	1,566,100	855,400	1,016,500	1,929,200
Calaveras River	380,700	82,000	68,200	241,300	211,300	424,400	160,100	294,300	39,400	160,500	67,100	175,500	95,300	192,600	334,200
Mokelumne River	2,011,600	522,900	691,100	1,223,400	909,900	1,408,300	595,400	1,016,000	423,000	461,700	647,600	1,049,500	647,500	777,900	1,288,200
Cosumnes River	944,200	120,900	183,600	505,000	332,300	693,800	157,400	507,000	112,200	121,800	159,100	403,800	151,200	238,600	393,600
Totals	24,266,300	9,571,800	11,366,900	14,564,400	11,713,900	18,615,200	9,267,200	12,127,400	4,706,700	6,337,400	7,302,100	14,499,600	8,192,500	9,161,100	11,168,200

Stream	Run-off, in acre-feet														
	1904–05	1905–06	1906–07	1907–08	1908–09	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16	1916–17	1917–18	1918–19
Kern River	548,000	1,837,100	1,053,600	467,800	1,759,800	739,500	1,002,000	420,900	357,800	1,094,300	663,600	2,462,800	871,800	514,300	532,400
Tule River[1]	92,300	464,400	200,700	104,000	383,300	151,700	145,600	65,000	38,200	163,100	136,700	336,400	176,500	51,300	76,300
Kaweah River	337,700	1,088,400	593,500	252,600	799,900	409,200	546,000	207,400	220,700	486,000	369,500	762,200	471,500	229,700	289,200
Kings River	1,427,800	3,856,700	2,752,500	1,033,900	2,809,400	1,779,000	2,826,700	968,100	941,800	2,548,400	1,817,100	3,041,800	1,892,600	1,363,700	1,203,300
San Joaquin River	1,605,100	3,893,200	2,924,700	1,264,200	2,821,400	2,087,900	3,535,800	1,163,900	888,100	2,770,000	2,006,800	2,759,600	1,959,300	1,545,900	1,353,100
Fresno River	109,300	142,900	104,000	30,500	82,100	38,500	108,600	31,700	19,200	48,600	63,400	109,100	71,400	40,300	35,300
Chowchilla River	74,600	124,300	142,900	22,400	90,700	59,600	114,300	19,900	16,200	87,000	82,000	53,400	39,800	33,600	48,500
Merced River	774,900	1,890,600	1,979,500	390,800	1,340,200	942,200	1,907,500	390,500	298,000	1,281,800	972,000	1,324,400	991,100	707,500	582,100
Tuolumne River	1,438,700	2,709,000	3,273,300	1,039,500	1,715,000	1,070,600	2,856,100	883,700	1,040,100	1,695,400	1,425,400	1,863,400	1,739,000	1,157,200	1,132,600
Stanislaus River	868,600	2,286,200	2,724,600	528,800	1,808,100	1,289,900	2,234,100	507,100	481,800	1,642,600	1,193,400	1,551,900	1,266,000	719,300	668,900
Calaveras River	93,100	383,400	662,200	57,900	334,300	154,500	626,000	51,400	26,600	212,500	218,800	304,000	300,300	184,100	69,500
Mokelumne River	652,100	1,298,900	1,635,200	521,700	1,094,500	914,300	1,468,500	439,300	354,000	1,027,900	804,600	1,004,000	843,700	520,400	568,900
Cosumnes River	169,600	434,300	692,700	97,800	464,000	352,300	714,100	93,900	69,500	358,900	267,000	461,800	278,400	134,300	155,600
Totals	8,191,800	20,469,400	18,739,400	5,811,900	15,502,700	10,589,200	18,145,300	5,242,800	4,752,000	13,416,500	10,020,900	16,034,800	10,901,400	7,201,600	6,715,700

Stream	Run-off, in acre-feet										Mean run-off for period, in acre-feet			
	1919–20	1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	1928–29	1889–1929	1909–1929	1919–1929	1924–1929
Kern River	589,300	517,200	841,600	522,000	189,900	465,600	340,700	796,000	337,600	328,800	714,000	679,000	493,000	454,000
Tule River[1]	111,800	90,500	139,700	102,000	24,700	89,800	48,900	131,000	48,200	54,800	130,000	109,000	84,100	74,500
Kaweah River	372,100	360,800	461,100	363,500	101,700	325,500	218,800	483,200	203,000	222,800	443,000	355,000	311,000	291,000
Kings River	1,404,700	1,532,300	2,197,600	1,555,900	392,000	1,290,200	1,037,200	1,984,200	970,900	849,300	1,889,000	1,580,000	1,321,000	1,226,000
San Joaquin River	1,310,600	1,559,900	2,279,500	1,683,500	645,000	1,281,300	1,235,200	1,885,700	1,219,700	878,700	1,993,000	1,702,000	1,398,000	1,300,000
Fresno River	37,800	43,000	68,600	63,700	14,400	34,700	25,100	58,800	34,600	17,000	55,200	48,200	39,800	34,000
Chowchilla River	32,300	77,000	107,600	68,400	7,600	85,000	31,700	69,800	52,000	36,800	70,900	56,200	56,900	55,100
Merced River	573,300	891,400	1,295,100	812,800	180,300	785,200	513,600	968,100	638,700	388,900	989,000	825,000	705,000	659,000
Tuolumne River	1,140,400	1,561,600	1,491,200	1,530,700	523,500	1,441,300	961,400	1,536,900	1,256,400	963,900	1,634,000	1,393,000	1,240,000	1,230,000
Stanislaus River	622,700	1,143,700	1,314,600	1,016,400	190,800	1,102,600	512,300	1,234,900	847,200	401,000	1,239,000	997,000	839,000	820,000
Calaveras River	58,600	167,000	172,800	136,400	28,200	99,500	51,300	124,000	89,600	36,300	189,000	156,000	96,400	80,100
Mokelumne River	422,600	830,400	876,900	676,600	260,100	716,800	385,700	807,000	645,800	350,100	820,000	696,000	597,000	581,000
Cosumnes River	100,900	220,400	285,000	332,000	36,600	204,800	95,700	268,500	208,500	68,400	290,000	235,000	182,000	169,000
Totals	6,777,100	8,995,200	11,531,300	8,863,800	2,594,800	7,922,300	5,457,600	10,348,100	6,552,200	4,586,800	10,456,100	8,831,400	7,363,200	6,973,700

[1] Includes South Fork of Tule River, which enters the main Tule below the reservoir site of the State Plan.

that, where available, sufficient upstream storage would be constructed to effect this service. In determining the irrigation requirements, the net use of water and its seasonal distribution were taken from a previous bulletin.* Net uses of 60 and 65 per cent of the gross diversions were assumed for foothill areas north and south of Stanislaus River, with 40 and 35 as the percentages of return flow to the same stream either above or below the reservoir site or to some other stream. Allowances were made for diversions out of the watershed for irrigation purposes on the Cosumnes, Mokelumne, Stanislaus, and Merced rivers. Monthly adjustments for the impounding in and release of stored water from assumed upstream irrigation and present constructed power reservoirs were made as though such reservoirs had been in existence throughout the 40-year period, 1889–1929.

It was assumed that the city of San Francisco would ultimately desire to divert 400,000,000 gallons per day from the Tuolumne River watershed for municipal purposes. The water available for this diversion is limited by the provisions of the Raker Act and was assumed to be regulated by the city's ultimate storage development. It was also assumed that the East Bay Municipal Utility District would ultimately divert 200,000,000 gallons per day from the Mokelumne River for municipal purposes. As this diversion is from the Pardee Reservoir, the foothill reservoir used on the Mokelumne River under the ultimate State Plan, it was not deducted from the total ultimate water supply obtainable from that reservoir. The estimated ultimate net seasonal run-off for each of the major San Joaquin River Basin streams is shown in Table 6.

Net Run-off Under Existing Conditions of Development. The monthly full natural run-off of each of the lower east side tributaries of the San Joaquin River Basin, at the foothill gaging stations, was corrected for the 12-year period, 1917–1929, to that which might be expected under conditions of irrigation development as of the present and municipal diversions estimated as of 1940, both above and below the gaging stations and for storage in and release from present constructed reservoirs at the foothill sites and in the mountains. The foothill reservoirs were assumed to be operated for irrigation purposes with the exception of Pardee Reservoir on the Mokelumne River, which was assumed to be operated for municipal purposes with some incidental power. The present constructed mountain reservoirs were assumed to be operated mainly for power purposes. The diversions for municipal purposes as of 1940 were estimated as 35,000,000 gallons per day or 54 cubic feet per second from the Tuolumne River watershed by the city of San Francisco and 75,000,000 gallons per day or 116 cubic feet per second from the Mokelumne River by the East Bay Municipal Utility District. The net run-off of each of the lower east side tributaries under the existing and assumed conditions of development determines the inflow into the San Joaquin River Delta. The estimated values for the 12–year period 1917–1929, are set forth by seasons in Table 7.

Variation of Run-off. Due to large fluctuations in precipitation in California, there are very wide variations in seasonal, monthly and

* Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, State Department of Public Works, 1923.

TABLE 7

SEASONAL NET RUN-OFF FROM SAN JOAQUIN RIVER BASIN INTO SAN JOAQUIN DELTA FOR THE PERIOD 1917-1929 UNDER CONDITIONS OF IRRIGATION AND STORAGE DEVELOPMENTS AS OF 1929 AND MUNICIPAL DIVERSIONS AS OF 1940

Season	Run-off, in acre-feet							Pumping diversions below gaging stations, in acre-feet	Run-off into San Joaquin Delta, in acre-feet
	San Joaquin River at Newman	Tuolumne River at confluence with San Joaquin River	Stanislaus River at confluence with San Joaquin River	Calaveras River at Jenny Lind	Mokelumne River below Woodbridge	Dry Creek near Ione	Cosumnes River below Michigan Bar		
1917-18	1,336,100	1,002,100	644,100	212,200	439,000	46,200	220,700	89,300	3,811,100
1918-19	1,139,900	840,000	497,400	97,300	484,100	61,100	258,300	89,300	3,288,800
1919-20	683,300	819,000	436,900	83,200	384,400	34,100	168,500	89,300	2,520,100
1920-21	1,405,200	1,394,600	930,100	221,900	646,300	103,000	404,200	89,300	5,016,000
1921-22	3,190,400	1,908,600	1,148,100	220,500	768,600	86,300	423,200	89,300	7,656,400
1922-23	1,672,000	1,241,800	841,100	181,100	600,800	135,000	435,500	89,300	5,018,000
1923-24	305,700	493,700	147,600	23,700	326,800	3,300	42,200	89,300	1,253,700
1924-25	733,700	1,092,800	884,000	159,100	475,700	83,700	255,900	89,300	3,595,600
1925-26	672,300	729,200	432,200	65,300	416,900	32,200	146,400	89,300	2,405,200
1926-27	1,807,400	1,276,900	1,031,300	181,000	606,400	96,100	449,800	89,300	5,359,600
1927-28	857,500	1,077,300	743,700	130,400	570,600	69,100	313,100	89,300	3,672,400
1928-29	362,200	658,400	248,600	41,000	401,500	22,200	113,400	89,300	1,758,000
Mean for period, 1917-29	1,180,100	1,045,000	665,000	135,000	510,000	64,800	269,000	89,300	3,779,600

daily run-off. It has been shown previously that there is a wide variation in seasonal precipitation over the San Joaquin River Basin. Since run-off is dependent upon precipitation, it will have generally similar variations. Run-off, however, is affected by the intensity and order of occurrence of storms, and its seasonal variation from normal, therefore, may not be exactly the same as the variation of the seasonal precipitation from its normal. The variation in seasonal precipitation over the San Joaquin River Basin is shown by the indices of wetness in Table 3, and the variation in run-off from the watersheds of the major streams of the San Joaquin River Basin is shown by the seasonal run-offs for these streams given in Table 5. The mean seasonal full natural run-offs, and minimum and maximum seasonal run-offs in acre-feet and in per cent of mean seasonals for the 40-year period, 1889–1929, are given in Table 8 for the major streams. These figures show that, for the major streams of the San Joaquin River Basin, the maximum seasonal run-off varies from 225 to 357 per cent and the minimum from 10 to 28 per cent of the mean seasonal for the 40-year period.

The monthly run-off varies more widely than the seasonal run-off. Most of the run-off from the rain which falls on the lower areas finds its way quickly into the stream channels while the snow in the higher mountain regions usually does not melt and appear as run-off until the late spring or early summer. The run-off from melting snow forms the greater part of the stream flows during these seasons. The unequal monthly distribution of the seasonal run-off from the drainage basins of each major stream of the San Joaquin River Basin, except the Chowchilla River, is illustrated in Table 9. Due to the short period of stream flow record on the Chowchilla River, October 1, 1921–September 30, 1923, no attempt was made to estimate the average monthly distribution for the 40-year period, for that stream. The distribution of seasonal run-off during the period of stream flow record in a normal, maximum, and minimum season for the San Joaquin, Kings, and Kern rivers, respectively, is further illustrated graphically on Plate IV, "Distribution of Run-off of San Joaquin, Kings, and Kern Rivers for Typical Seasons." The variation in the daily run-off of any particular stream is greater than either the annual or monthly. The mean daily flows of the larger streams vary from a few second feet in the late summer to thousands of second feet during flood periods. These floods are caused by excessive precipitation in the form of rain during the winter months, by the rapid melting of the snow pack in the mountains during the late spring or early summer months, or by a combination of these causes. To illustrate this variation, the maximum and minimum mean daily flows of each major stream of the San Joaquin River Basin, except the Chowchilla River, are shown in Table 10. The minimum daily stream flows of the San Joaquin, Merced, Tuolumne, Stanislaus and Mokelumne rivers, during recent years, have been affected considerably by storage releases from upstream reservoirs. The proportional variations in daily stream flow of some of the minor streams are greater than for the major streams although records are not available for the determination of maximum variations on the minor streams. Occasionally these streams are torrents due to concentrated rain storms on their watersheds and at other times they are entirely dry.

TABLE 8

VARIATION IN SEASONAL RUN-OFF FOR MAJOR STREAMS IN THE SAN JOAQUIN RIVER BASIN, 1889-1929

Based on full natural run-off for 40-year period 1889-1929

Stream	Point of measurement	Mean seasonal run-off, in acre-feet	Maximum seasonal run-off in 40-year period			Minimum seasonal run-off in 40-year period		
			In acre-feet	In per cent of mean seasonal run-off	Season	In acre-feet	In per cent of mean seasonal run-off	Season
Cosumnes River	At Michigan Bar	407,000	1,151,000	283	1889–1890	40,400	10	1923–1924
Mokelumne River	Near Clements	853,000	2,063,000	242	1889–1890	190,000	22	1923–1924
Calaveras River	At Jenny Lind	227,000	708,000	312	1906–1907	23,700	10	1923–1924
Stanislaus River	Near Knights Ferry	1,350,000	3,230,000	239	1889–1890	261,000	19	1923–1924
Tuolumne River	Near La Grange	2,070,000	5,099,000	246	1889–1890	546,000	26	1923–1924
Merced River	Near Merced Falls and at Exchequer	1,115,000	2,745,000	246	1889–1890	252,000	23	1923–1924
Fresno River	Near Knowles	63,400	168,000	266	1889–1890	14,400	23	1923–1924
Chowchilla River	Near Buchanan Reservoir Site	70,900	195,000	275	1889–1890	7,600	11	1923–1924
San Joaquin River	Near Friant	1,995,000	4,620,000	232	1889–1890	446,000	22	1923–1924
Kings River	At Piedra	1,889,000	4,250,000	225	1889–1890	392,000	21	1923–1924
Kaweah River	Near Three Rivers	443,000	1,100,000	248	1889–1890	102,000	23	1923–1924
Tule River	Near Porterville	135,000	482,000	357	1905–1906	25,600	19	1923–1924
Kern River	Near Bakersfield	725,000	2,474,000	341	1915–1916	202,000	28	1923–1924

TABLE 9

AVERAGE MONTHLY DISTRIBUTION OF SEASONAL RUN-OFF OF MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

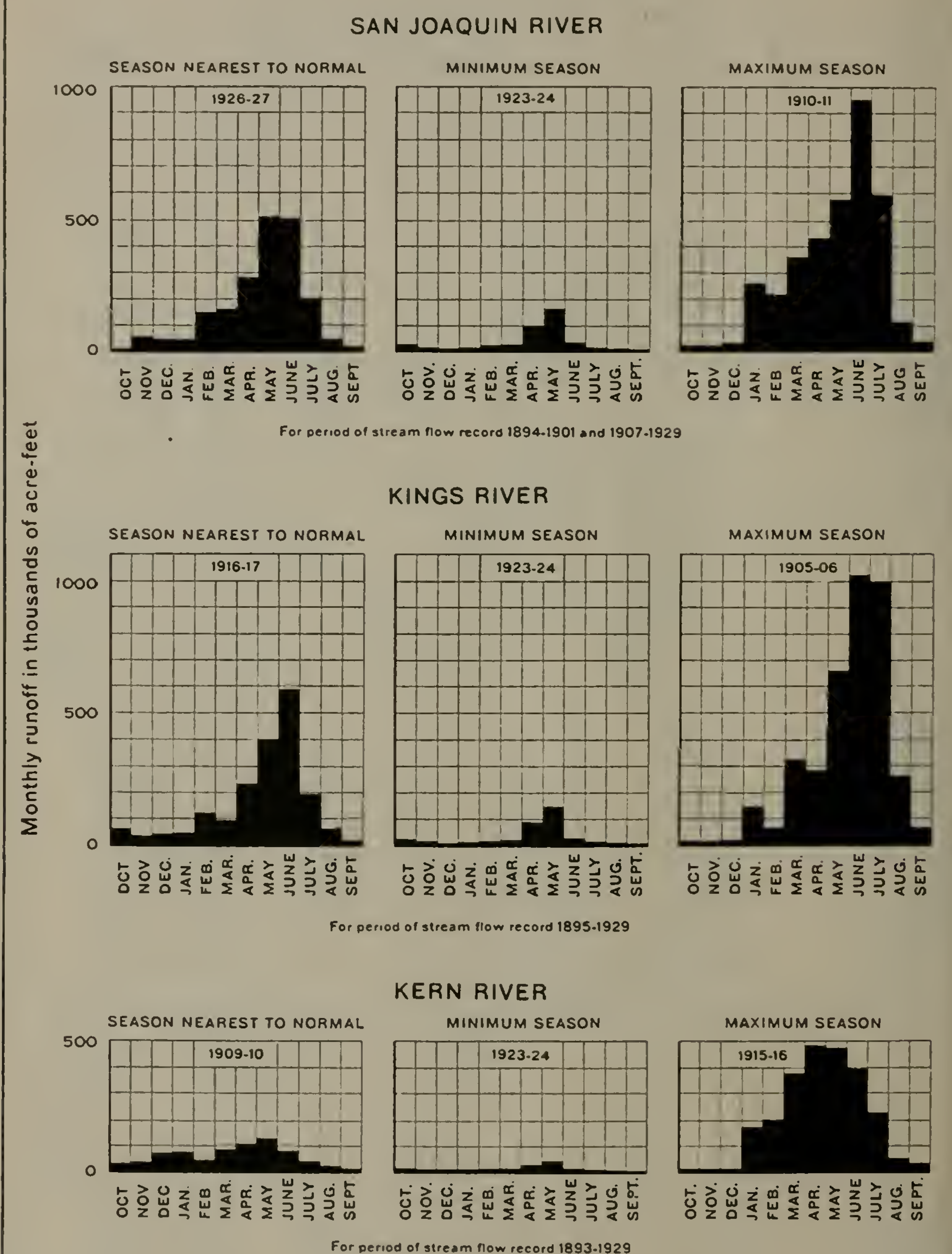
Based on mean full natural run-offs for 40-year period, 1889-1929

Month	Kern River near Bakersfield		Tule River near Porterville		Kaweah River near Three Rivers		Kings River at Piedra	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	18,200	2.5	1,700	1.3	6,200	1.4	27,800	1.5
November	18,900	2.6	3,100	2.3	8,400	1.9	29,400	1.6
December	21,700	3.0	6,800	5.0	11,500	2.6	35,400	1.9
January	35,500	4.9	15,000	11.1	26,500	6.0	78,700	4.2
February	39,200	5.4	15,000	11.1	26,400	6.0	76,500	4.0
March	64,200	8.8	23,800	17.6	45,300	10.2	133,000	7.0
April	102,000	14.1	26,200	19.4	69,500	15.7	240,000	12.7
May	153,000	21.1	24,400	18.1	110,000	24.8	490,000	25.9
June	145,000	20.0	13,100	9.7	93,000	21.0	483,000	25.6
July	77,500	10.7	3,600	2.7	33,200	7.5	208,000	11.0
August	32,600	4.5	1,300	1.0	8,400	1.9	61,500	3.2
September	17,200	2.4	1,000	0.7	4,600	1.0	25,700	1.4
Totals	725,000	100.0	135,000	100.0	443,000	100.0	1,889,000	100.0

Month	San Joaquin River near Friant		Fresno River near Knowles		Merced River at Exchequer		Tuolumne River near La Grange	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	27,700	1.4	500	0.8	13,300	1.2	22,200	1.1
November	31,600	1.6	2,000	3.1	18,000	1.6	37,000	1.8
December	44,000	2.2	3,700	5.8	26,600	2.4	60,700	2.9
January	92,100	4.6	6,900	10.9	68,300	6.1	118,000	5.7
February	94,600	4.7	13,300	21.0	81,900	7.4	149,000	7.2
March	163,000	8.2	14,700	23.2	130,000	11.6	221,000	10.7
April	267,000	13.4	11,400	18.0	171,000	15.3	310,000	15.0
May	494,000	24.8	6,000	9.5	280,000	25.1	498,000	24.0
June	479,000	24.0	3,500	5.5	226,000	20.3	446,000	21.5
July	210,000	10.5	1,200	1.9	75,300	6.8	167,000	8.1
August	64,300	3.2	200	0.3	17,000	1.5	30,600	1.5
September	27,700	1.4	0	0	7,600	0.7	10,500	0.5
Totals	1,995,000	100.0	63,400	100.0	1,115,000	100.0	2,070,000	100.0

Month	Stanislaus River near Knights Ferry		Calaveras River at Jenny Lind		Mokelumne River near Clements		Cosumnes River at Michigan Bar	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	12,100	0.9	1,400	0.6	6,700	0.8	2,000	0.5
November	21,200	1.6	4,400	1.9	17,500	2.0	5,800	1.4
December	35,600	2.6	18,500	8.2	28,000	3.3	26,100	6.4
January	84,100	6.2	50,800	22.4	48,800	5.7	57,600	14.2
February	109,000	8.1	53,300	23.5	66,400	7.8	74,200	18.2
March	176,000	13.1	65,700	29.0	104,000	12.2	90,500	22.2
April	246,000	18.2	21,600	9.5	148,000	17.4	75,400	18.5
May	335,000	24.8	7,600	3.4	216,000	25.3	51,200	12.6
June	232,000	17.2	3,000	1.3	163,000	19.1	20,200	5.0
July	73,900	5.5	500	0.2	46,900	5.5	3,000	0.8
August	16,700	1.2	100	0	5,100	0.6	500	0.1
September	8,400	0.6	100	0	2,600	0.3	500	0.1
Totals	1,350,000	100.0	227,000	100.0	853,000	100.0	407,000	100.0

PLATE IV



DISTRIBUTION OF RUN-OFF

OF

SAN JOAQUIN, KINGS AND KERN RIVERS

FOR TYPICAL SEASONS

TABLE 10

MAXIMUM AND MINIMUM MEAN DAILY STREAM FLOWS IN MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

Stream	Gaging station	Maximum flow		Minimum flow	
		In second feet	Date	In second feet	Date
Cosumnes River	At Michigan Bar	22,400	Jan. 31, 1911	0	[1]
Mokelumne River	Near Clements	23,400	Mar. 19, 1907	0	July 9, 1924[2]
Calaveras River	At Jenny Lind	69,600	Jan. 31, 1911	0	[3]
Stanislaus River	Near Knights Ferry	57,200	Mar. 19, 1907	0	Dec. 3-5, 1912
Tuolumne River	Near La Grange	52,500	Jan. 30, 1911	1	Nov. 26-Dec. 1, 1922[4]
Merced River	Near Merced Falls and at Exchequer	37,200	Jan. 30, 1911	0	Nov. 21, 1901
Fresno River	Near Knowles	3,770	Feb. 21, 1917	0	[5]
San Joaquin River	Near Friant	38,800	Jan. 31, 1911	54	Monday, Sept. 15, 1924[6]
Kings River	At Piedra	46,300	Jan. 7, 1901	67	Oct. 2, 3, 1924
Kaweah River	Near Three Rivers	10,100	Jan. 17, 1916	10	Aug. 29-Sept. 1, 1924
Tule River	Near Porterville	5,430	Dec. 8, 1909	0	Sept. 27-Oct. 1, 1926
Kern River	Near Bakersfield	16,100	Jan. 18, 1916	82	Sept. 16, 1924

[1] Part of 1908, 1918, 1919, 1924, 1926.
[2] Also August 15 and 20-23, 1924.
[3] Part of 1913, 1914, 1915, 1917, 1918, 1919, 1920, 1921, 1922, 1924, 1925, 1926, 1927, 1928, 1929.
[4] Flow shut off by closure of gates at Don Pedro Dam.
[5] Aug., Sept., 1919; July-Oct., 1924; Aug., Sept., 1926; Aug.-Oct., 1928, and Aug., Sept., 1929.
[6] Due to retention of inflow in power storage over week end. Average for week September 14-21, 182 second-feet.

Return Water.

In the San Joaquin River Basin a substantial potential water supply is that from water which, once used for irrigation, domestic or other purposes, would return to the streams either as direct drainage or as an inflow from the various underground basins. The return irrigation waters would have their sources in the losses from canals or other conduits during conveyance of water from the points of diversion on the streams to points of use, in the surface drainage from the land after irrigation and in seepage to the underground basins. A large portion of the return waters from the mountain and foothill region would be available for storage in the major unit reservoirs of the State Water Plan in which they could be regulated to a supply conforming to the irrigation demand on the valley floor. In the upper San Joaquin Valley most of the waters diverted to the valley floor in excess of consumptive use would be utilized by pumping from underground reservoirs. The efficient utilization of these underground reservoirs would allow only a small portion of this water to reach the valley trough channels. In the lower San Joaquin Valley the waters diverted to the valley floor in excess of consumptive use would enter the streams or artificial drains and finally reach the San Joaquin River or would replenish the underground basins. The return waters reaching the San Joaquin River could be made available for reuse on adjacent lands or exportation to other areas through the major conveyance units of the State Water Plan and would be intermingled with water imported from the Sacramento River Basin.

The suitability of these return waters for reuse is of importance because it would constitute a considerable part of the total available water supply for the San Joaquin River Basin. During 1906 and 1908 at regular intervals throughout each of the respective years, and in

1930 during the low water season, the Water Resources Branch of the United States Geological Survey chemically analyzed water samples taken from many of the principal streams of the State. Among these were analyses of water from the San Joaquin River when nearly the entire flow was return water from irrigation. The locations and the dates of taking these water samples and the results of the analyses are set forth in Appendix E, "The Chemical Character of Some Surface Waters of California, 1930–1932." These analyses, as well as analyses presented in another report,* show that the return water, under present conditions, is entirely satisfactory, chemically, for municipal, irrigation and industrial uses and can be classified as "good."

The amounts and distribution of return waters throughout the season also are important elements in determining the feasibility of utilizing return waters. In order to determine these values as accurately as possible, measurements of diversions and return waters have been made each season since 1924 by the Sacramento-San Joaquin Water Supervisor. Results of these measurements are given in a bulletin of the Division of Water Resources.** From 1924 to 1927, inclusive, three series of measurements were taken, each season, along each major stream of the lower San Joaquin Valley, beginning near the foothills and ending at the mouth. Estimates were made en route, of all diversions between each point of measurement. In 1928, permanent gaging stations were established at the upper and lower point on each stream. For each season since 1927, during the June to October periods, continuous flow records and estimates of diversion have been obtained. The points of stream flow measurement are located at the Yosemite Valley Railroad crossing near Snelling and the bridge of Hills Ferry Road on Merced River; Roberts Ferry Bridge and Tuolumne City on Tuolumne River; Orange Blossom Bridge and Elliott Ranch on Stanislaus River; and at San Luis Ranch, below the mouth of the Merced River near Newman, near Grayson and near Vernalis on San Joaquin River. These stream flow measurements were analyzed in conjunction with records and estimates of diversions to determine the amounts of water which returned to the respective river channels during the period of measurement. As measurements were taken from June to October only, the natural run-off from valley floor lands was eliminated from consideration.

The measurements covered seasons of both large and small total stream flow and the character of the season probably affected the percentage of return water. Greater amounts of water are diverted in seasons of large stream flow than in seasons of smaller yield, and since only a definite amount is consumed by plant growth, the return flows in seasons of large water yield represent a somewhat larger percentage of the total diversions.

Analyses of measurements of surface diversion into, and measurements of outflow from a large fully developed district in the lower San Joaquin Valley, for the 1929 irrigation season, showed a total seasonal return flow of 36 per cent of the gross diversion. From gross diversion

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, State Department of Public Works, 1931.

** Bulletin No. 23, "Report of Sacramento-San Joaquin Water Supervisor," Division of Water Resources, State Department of Public Works, 1930.

and net use analyses presented in Chapter VII, it is estimated that, under conditions of ultimate development, the average proportion of return flow would be about 40 per cent of all of the water diverted from both local and imported supplies for irrigation in the lower San Joaquin Valley, and would be available, in the stream channels, for reuse on adjacent lands or exportation to other areas. During the principal months of the irrigation season practically all of such return flows would be utilized for these purposes.

There is no definite information on the amounts of irrigation water which return slowly to the stream channels during the winter months. An accurate determination of these amounts would be difficult as they are combined with run-offs from rainfall on the valley floor. Estimates, however, have been made of the amounts of return water for the winter season. Studies indicate that during the period, 1924–1929, the return water in the months from July to September, inclusive, in different seasons, varied from 19 to 38 per cent of the diversion for these months. It is estimated that the return flow from general crop irrigation during the principal irrigation months, April to October, inclusive, is about 65 per cent of the total seasonal, and it has been assumed that the remaining 35 per cent returns at about a uniform rate over the other five months. Table 11 sets forth the estimated monthly distribution of return waters in the lower San Joaquin Valley.

TABLE 11

MONTHLY DISTRIBUTION OF RETURN WATERS IN LOWER SAN JOAQUIN VALLEY

Month	Return water in per cent of total seasonal return	Month	Return water in per cent of total seasonal return
October	8	April	7
November	7	May	8
December	7	June	11
January	7	July	12
February	7	August	10
March	7	September	9

CHAPTER III

AGRICULTURAL LANDS

The San Joaquin River Basin, embracing an area of about 32,000 square miles or 20.6 per cent of the State's total, contains within its exterior boundaries, valley, foothill and mountain lands. The uses of water in this area and on these lands include domestic, municipal, irrigation, salinity control, industrial, navigation, power and recreation. Of all the foregoing uses, that for the irrigation of the farm lands in the basin does and probably will continue to predominate. It is believed that the water requirements estimated on the basis of irrigation would be adequate for the future complete development of the basin. Therefore, it was important and necessary in these investigations to determine as nearly as practicable the extent of the agricultural lands in the basin which have been brought under irrigation and of those lands not now irrigated but susceptible of irrigation at some future time. This involved a survey of the basin for the purpose of classifying the lands.

Geology and Soils.

The character of the soils in the San Joaquin Valley is related to its geological history. The following general description of the geology of the valley is quoted from Water Supply Paper 398 of the U. S. Geological Survey:

"The valley as a whole is a great structural trough and appears to have been such a basin since well back in Tertiary time. Since it assumed its general troughlike form, gradual subsidence, perhaps interrupted by periods of uplift, has continued and has been accompanied by deposition alternating at least along what is now its western border with intervals of erosion. This interrupted but on the whole continuous deposition seems to have been marine during the early and middle Tertiary; but during the later Tertiary and Pleistocene, when presumably the valley had been at least roughly outlined by the growth of the Coast Ranges, fresh water and terrestrial conditions became more and more predominant, until the relations of land and sea, of rivers and lakes, of coast line and interior, of mountain and valley, as they exist now, were gradually evolved. As these conditions developed, the ancestors of the present rivers probably brought to the salt and fresh water bodies that occupied the present site of the valley and its borders, or, in the latest phases of the development, to the land surface itself, the clays, sands, gravels, and alluvium that subsequently consolidated into the shales, sandstones, and conglomerates of the late Tertiary and Pleistocene series, just as the present rivers are supplying the alluvium that is even now accumulating over the valley floor.

"The very latest of these accumulations are the sand and silt and gravel beds penetrated by the driller in his explorations for water throughout the valley. They are like the early folded sandstones, shales and conglomerates exposed along the flanks of the valley, except that they are generally finer, and are not yet consolidated or disturbed. The greater part, perhaps all of them, accumulated as stream wash on the valley surface or in interior lakes like the present Tulare Lake, but a proportion of the older sediment that is greater as we delve farther back into the geologic past accumulated in the sea or in salt bays having free connection with the sea. It is these very latest geologic deposits, saturated below the ground water level by the fresh water supplied chiefly by the Sierran streams, that constitute the reservoirs drawn upon by the wells, whether flowing or pumped, throughout the valley."

All of the five general groups of soils, residual, old valley-filling, recent alluvial, lake-laid and wind-laid, are found within the San Joaquin River Basin. The residual soils occur in the foothill and mountain areas. The portions of these areas in which disintegration has proceeded without erosion form much of the agricultural lands within the foothills and along the edges of some portions of the valley. The old valley-filling soils occur as terraces along streams, remnants of alluvial fans or higher valley areas. The hardpan soils are mainly of this type. The recent alluvial soils represent the recent stream deposits in the valley and along stream channels. The lake-laid soils, mainly of fine texture, have been deposited in lakes of fluctuating volume in flat poorly drained basins in the valley trough and merge gradually with the recent alluvial soils. Wind-laid soils have been deposited as the result of wind action on adjacent light-textured alluvial soils and, in places, closely resemble sand dunes. The old valley-filling and recent alluvial soils represent much the larger part of the agricultural lands.

Land Classification.

Considerable data on land classification in the San Joaquin Valley were available from other sources prior to the undertaking of the investigations on which this report is based. The reports and maps of the U. S. Bureau of Soils were available for the entire valley area. These reports show soil texture and alkali. The maps of the U. S. Geological Survey were available for all but the south end of the valley, on a scale of two inches to the mile with five-foot contour intervals which indicated the roughness of the land. Many local areas had been classified in prior investigations for procedure before the State Engineer relative to irrigation, water storage and water conservation districts. Classifications in such areas were reviewed and utilized as far as practicable.

Standards of classification were established prior to starting a field examination and were maintained throughout the survey. Boundaries between the classes were located on field maps on a scale of two inches per mile. The quadrangle sheets of the U. S. Geological Survey were used where available. Full use also was made of the Reconnaissance Soil Survey maps of the U. S. Bureau of Soils. Field notes were placed directly on the maps. Areas of each classification on each map were measured in the office by means of the planimeter, their totals checked against the total area and then segregated by hydrographic divisions and counties. Land classification is necessarily, to a large extent, a matter of judgment. It was not considered possible to exactly locate the boundaries of areas in each classification and because of limited time and funds refinements were not attempted. However, the areas determined for each classification, as a whole, are believed to be substantially correct.

The total area included within the San Joaquin River Basin consists of valley, foothill and mountain areas. While exact lines of demarcation are difficult to locate, especially between foothill and mountain lands, the total area was divided into three segregations in this investigation, as set forth in Table 12. All of the valley areas were carefully classified in order to determine the portions which would justify development under irrigation. The portions of the foothill areas containing agricultural lands also were classified. The field work on land classification in connection with this report was not extended into the remaining foothills and mountains above the irrigable areas.

TABLE 12

SEGREGATION OF LANDS IN SAN JOAQUIN RIVER BASIN

Segregation	Area	
	In square miles	In per cent of total
Valley lands	13,000	40.6
Classified foothill areas	1,500	4.7
Unclassified foothills and mountains	17,500	54.7
Totals	32,000	100.0

Much of the gross area in these three divisions is nonagricultural in character. All of the mountain and unclassified foothill areas are considered to be nonagricultural. In the valley and classified foothill areas, exclusive of 279,000 acres in the San Joaquin Valley portion of the Sacramento-San Joaquin Delta, about 12,840 square miles have been classified as agricultural, which represents 92 per cent of the gross area of these two divisions and is equal to 8,219,400 acres.

Valley Floor Lands. The methods and standards employed in classifying the valley floor lands are set forth in a rather complete discussion in Appendix A. For that reason only a brief description of the standards of classification used for these lands is given in this chapter.

Class 1 represents those lands where the soil texture, alkali or topography, do not limit the crop yield or the feasibility of irrigation. These are good lands capable of producing high yields at reasonable costs of preparation.

Class 2 represents lands of medium ability to carry costs for water. These are second-grade lands where the difference from Class 1 may be due to hardpan, roughness, alkali or other factors.

Class 3 represents lands which by present standards do not justify irrigation with regulated water supplies, but which may eventually come into Class 2 with improvements in methods of alkali removal or reduction in costs of leveling. These are areas which are not now suitable for irrigation, but where the conditions may not justify a present conclusion of permanent nonsuitability.

Class 4 represents lands suitable only for flooding for pasture and of too poor quality to be suited to the production of usual crops.

Class 5 represents lands which can be considered as permanently nonirrigable by any reasonable or probable future standards. The poor quality of the land may be due to alkali, shallow depths of soil, hardpan, roughness or steepness or a combination of these factors. These lands have been classified as nonagricultural.

Following the completion of the classification of the valley areas, maps showing the results were submitted to the San Joaquin Valley Water Committee and by it referred to the subcommittees for each of the eight counties involved. The classification was reviewed and, with minor exceptions, accepted by the county committees. On Plate V, "Classification of Agricultural Lands in the San Joaquin Valley," are delineated the areas classified under the foregoing standards. This plate shows in general the location of the areas falling within the

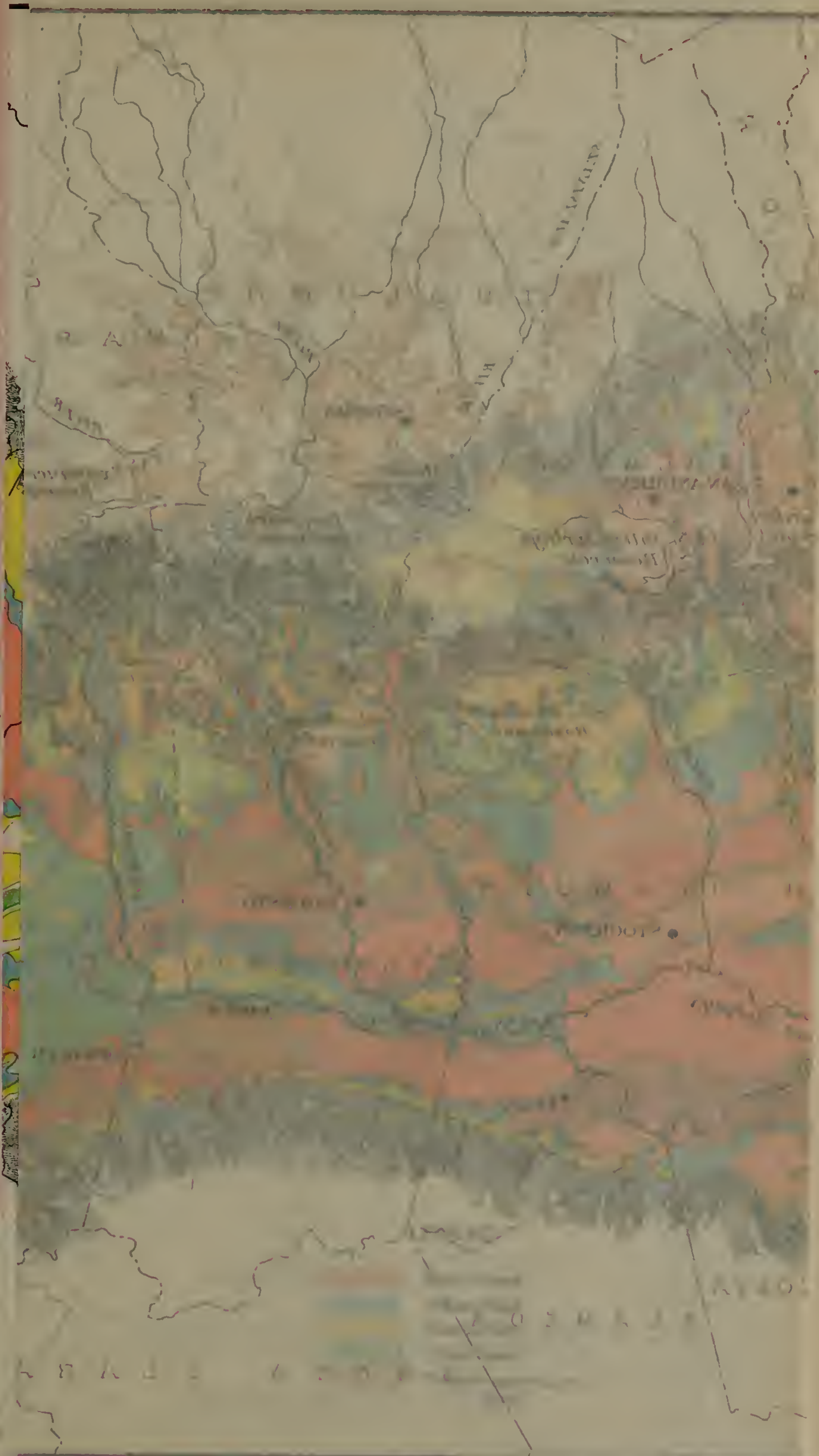


TABLE 12

SEGREGATION OF LANDS IN SAN JOAQUIN RIVER BASIN

Segregation	Area	
	In square miles	In per cent of total
Valley lands	13,000	40.6
Classified foothill areas	1,500	4.7
Unclassified foothills and mountains	17,500	54.7
Totals	32,000	100.0

Much of the gross area in these three divisions is nonagricultural in character. All of the mountain and unclassified foothill areas are considered to be nonagricultural. In the valley and classified foothill areas, exclusive of 279,000 acres in the San Joaquin Valley portion of the Sacramento-San Joaquin Delta, about 12,840 square miles have been classified as agricultural, which represents 92 per cent of the gross area of these two divisions and is equal to 8,219,400 acres.

Valley Floor Lands. The methods and standards employed in classifying the valley floor lands are set forth in a rather complete discussion in Appendix A. For that reason only a brief description of the standards of classification used for these lands is given in this chapter.

Class 1 represents those lands where the soil texture, alkali or topography, do not limit the crop yield or the feasibility of irrigation. These are good lands capable of producing high yields at reasonable costs of preparation.

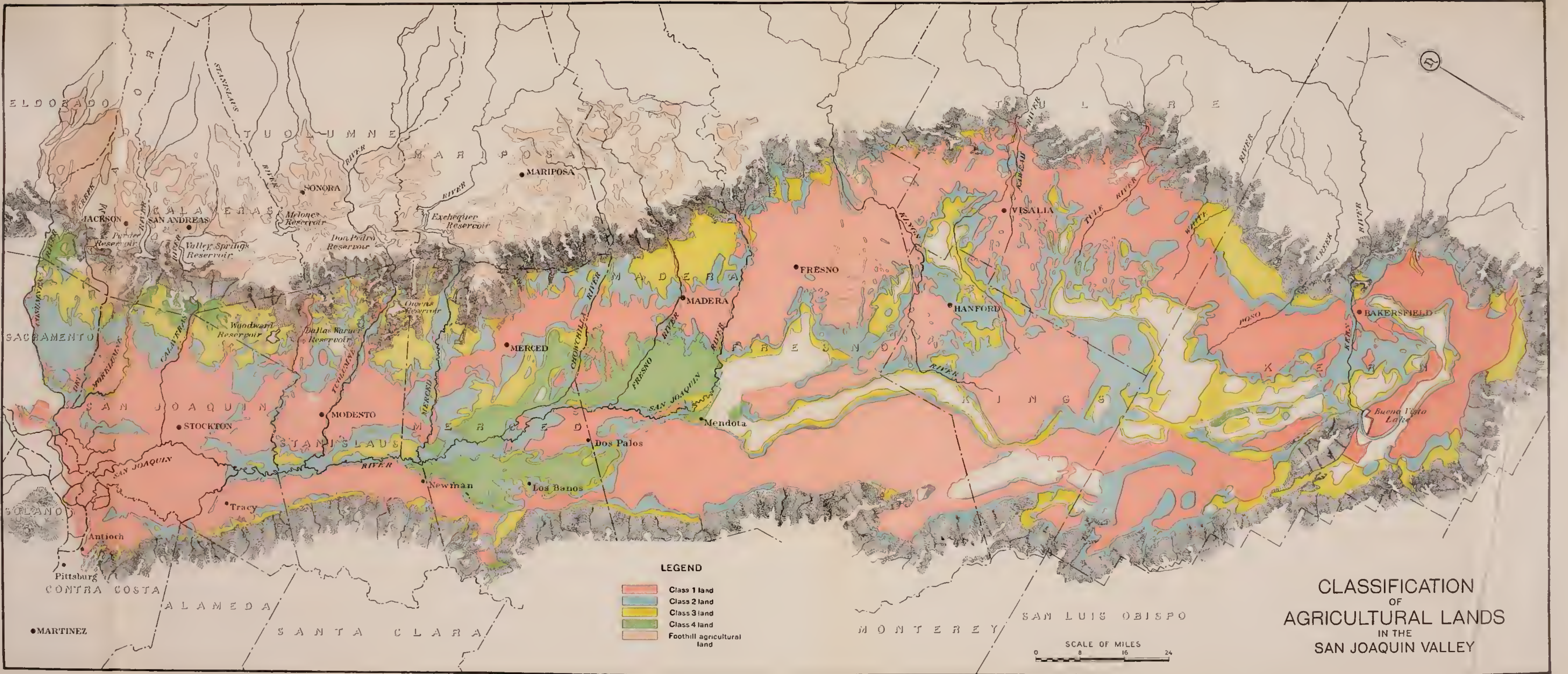
Class 2 represents lands of medium ability to carry costs for water. These are second-grade lands where the difference from Class 1 may be due to hardpan, roughness, alkali or other factors.

Class 3 represents lands which by present standards do not justify irrigation with regulated water supplies, but which may eventually come into Class 2 with improvements in methods of alkali removal or reduction in costs of leveling. These are areas which are not now suitable for irrigation, but where the conditions may not justify a present conclusion of permanent nonsuitability.

Class 4 represents lands suitable only for flooding for pasture and of too poor quality to be suited to the production of usual crops.

Class 5 represents lands which can be considered as permanently nonirrigable by any reasonable or probable future standards. The poor quality of the land may be due to alkali, shallow depths of soil, hardpan, roughness or steepness or a combination of these factors. These lands have been classified as nonagricultural.

Following the completion of the classification of the valley areas, maps showing the results were submitted to the San Joaquin Valley Water Committee and by it referred to the subcommittees for each of the eight counties involved. The classification was reviewed and, with minor exceptions, accepted by the county committees. On Plate V, "Classification of Agricultural Lands in the San Joaquin Valley," are delineated the areas classified under the foregoing standards. This plate shows in general the location of the areas falling within the


CLASSIFICATION
OF
AGRICULTURAL LANDS
IN THE
SAN JOAQUIN VALLEY
LEGEND
Class 1 land
Class 2 land
Class 3 land
Class 4 land
Foothill agricultural land
SCALE OF MILES
0 8 16 24
ELDORADO
TUOLUMNE
MARIPOSA
CALAVERAS
TULARE
MADERA
SACRAMENTO
SAN JOAQUIN
STANISLAUS
MERCED
FRESNO
KINGS
KERN
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
MONTEREY
SAN LUIS OBISPO
JACKSON
SAN ANDREAS
SONORA
MARIPOSA
VISALIA
FRESNO
HANFORD
MADERA
MERCED
BAKERSFIELD
MODESTO
STOCKTON
Mendota
Dos Palos
Newman
Los Banos
Tracy
Antioch
Pittsburg
MARTINEZ
Pardee Reservoir
Valley Springs Reservoir
Melones Reservoir
Don Pedro Reservoir
Exchequer Reservoir
Owens Reservoir
Woodward Reservoir
Dallas Warner Reservoir
Buena Vista Lake
SAN JOAQUIN RIVER
KINGS RIVER
TULE RIVER
WHITE RIVER
KERN RIVER
POSO
FRESNO RIVER
CHOWCHILLA RIVER
MERCED RIVER
TUOLUMNE
STANISLAUS
CALAVERAS
MOKELUMNE
COSUMNES RIVER
KAWEAH RIVER

various classifications. It should be noted particularly that the boundaries of such areas are not exact as to location and that the basic data for these areas were not obtained with a sufficient degree of accuracy to make this plate usable for the determination of soil characteristics or appraisals of individual tracts or other relatively small areas. Class 5 land is not considered agricultural and is not shown on the plate.

The boundary of the valley floor, south of the San Joaquin River, encompasses a large area of agricultural land out of proportion to the water crop from the adjacent tributaries available for use in its development. With an irrigation development already of such extent that in dry periods the yield of these tributary streams is entirely utilized, the shortage in supply in portions of the area is reflected in continuously receding ground water tables. The northern limit of the areas now under irrigation development where such conditions of disparity between supply and demand obtain is at the Chowchilla River. Northward from this line the available run-off from tributary streams is adequate to support all existing development. Nearly the entire now utilized run-off of the San Joaquin River proper serves an area northward from Mendota. Because of these differences in tributary water supply the San Joaquin Valley has been divided into two parts in this investigation. The portion southward from Mendota and the Chowchilla River has been designated as the upper San Joaquin Valley and that downstream or northerly from the above line of separation, as the lower San Joaquin Valley. The upper San Joaquin Valley extends southward to the southern limit of the Great Central Valley, and the lower San Joaquin Valley northward to Antioch on the west side of the valley and to the Cosumnes River on the east. Table 13 sets forth the areas of each of the five classes of land on the San Joaquin Valley floor. In this table, the area of each class of land in upper San Joaquin Valley; lower San Joaquin Valley, excluding San Joaquin Delta; and San Joaquin Delta is shown separately.

TABLE 13

CLASSIFICATION OF LANDS ON SAN JOAQUIN VALLEY FLOOR

Class	Upper San Joaquin Valley floor		Lower San Joaquin Valley floor, excluding San Joaquin Delta		San Joaquin Delta		Total San Joaquin Valley floor	
	Gross area		Gross area		Gross area		Gross area	
	In acres	In per cent of total	In acres	In per cent of total	In acres	In per cent of total	In acres	In per cent of total
1	2,886,900	52.2	1,063,500	44.3	261,000	93.5	4,211,400	51.3
2	1,051,500	19.0	674,500	28.1	17,000	6.1	1,743,000	21.2
3	772,700	14.0	402,700	16.7	1,000	0.4	1,176,400	14.3
4	170,700	3.1	219,900	9.1	0	0	390,600	4.8
5	647,400	11.7	43,500	1.8	0	0	690,900	8.4
Totals	5,529,200	100.0	2,404,100	100.0	279,000	100.0	8,212,300	100.0

In Tulare County, a land classification survey also was made by the Tulare County Water Committee. The classifications in that county for the two surveys are compared in Table 14.

TABLE 14

COMPARISON OF LAND CLASSIFICATIONS IN TULARE COUNTY

Class	Gross area, in acres	
	State	Tulare County water committee
1	578,900	633,486
2	234,500	190,834
3	90,100	113,726
4	0	0
5	79,200	201,050
Town sites, etc.		11,701
Sloughs and channels		7,913
Totals	982,700	1,158,710

The county classification included about 165,000 acres of Class 5 land above the area covered by the State. The division between the valley and the adjacent Class 5 hill-land was in general agreement in the two classifications. The sum of the Class 1 and 2 areas is closely in agreement in the two classifications, although the county classification rates a somewhat larger area as Class 1. A comparison of the results by local areas indicates that the principal differences are due to a more severe rating by the State of the alkali areas extending along the western side of the county. These lands are largely used for pasture with only limited areas of cultivated crops.

Foothill Lands. The foothill areas were classified on somewhat different standards than those used for the valley lands. The base maps available for the foothill areas are on a smaller scale and in much less detail than those available for the valley areas. The better lands occur as separate scattered areas within larger areas containing poorer lands. A detail mapping by individual areas was not practicable within the limits of these investigations. Five grades or classifications were used. Each class represented areas in which the net arable area was estimated to comprise the following percentages of the gross area:

Class 1—80 per cent
Class 2—80 per cent
Class 3—50 per cent and 60 per cent
Class 4—20 per cent and 40 per cent
Class 5— 0

For Classes 3 and 4, the percentage of arable land, for each of the individual areas, was estimated at one of the two values given. Only a small amount of Class 1 land was shown separately as many of the actual areas of Class 1 quality are included in the arable portions of the other classes. It was determined before classifying any of the lands as agricultural that it would be physically possible to develop a water supply for them, without regard, however, to the economic feasibility.

The principal factors affecting the irrigability of foothill lands are roughness and depth of soil. Roughness may consist of general steepness or of general irregularity of topography. In many areas the depth of the soil is insufficient for adequate root development. In general, the depth of soil increases toward the higher elevations where rainfall and frost action are greater. The field work was extended to an elevation of about 4000 feet. The arable lands above this elevation are limited principally to meadow areas along streams which are now largely developed. The stream flow is measured below such higher areas and their use of water is already reflected in the stream flow records. The total area of such lands is not of sufficient magnitude to require separate consideration.

The results of the classification of foothill lands are shown in Table 15. The numbers used to designate the different classes of foothill land do not represent the same basis of classification as for valley lands and the results shown in Table 15 for the foothill lands should not be compared with the results for the same numbered classes of valley lands in Table 13. The Class 5 foothill lands are those areas which do not contain irrigable lands and were not separately measured. Class 5 represents all lands not included in Classes 1 to 4 and is a part of the total area of 17,500 square miles of unclassified foothills and mountains.

TABLE 15

CLASSIFICATION OF AGRICULTURAL LANDS IN FOOTHILLS ADJACENT TO SAN JOAQUIN VALLEY FLOOR

Class	Gross area	
	In acres	In per cent of total
1	3,400	0.3
2	12,000	1.2
3	348,100	35.7
4	613,500	62.8
Totals	977,000	100.0

Classification by Counties. Although the same numbers are used for the classes of land in the foothills as for valley floor lands, it should be kept in mind in combining areas of lands under these classifications that they are on a somewhat different basis. Such a combination was made for Table 16 in which the total area of land in each of the first four classes is shown for that portion of each county in the upper and lower San Joaquin Valley and in the San Joaquin Delta. Since no attempt was made to measure the Class 5 lands in the foothills, this classification was omitted from the table and the total area shown for each county, therefore, is not the gross area of that county.

TABLE 16

CLASSIFICATION OF AGRICULTURAL LANDS IN SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS, BY COUNTIES

County	Gross area in acres				
	Class				Totals
	1	2	3	4	
Upper San Joaquin Valley—					
Kern	737,000	330,600	332,500	5,500	1,405,600
Kings	394,600	211,200	106,300	0	712,100
Tulare	578,900	234,500	90,100	0	903,500
Fresno	1,036,300	169,000	146,700	14,800	1,366,800
Madera	140,100	106,200	116,100	238,0C0	600,400
Totals	2,886,900	1,051,500	791,700	258,300	4,988,400
Lower San Joaquin Valley, excluding San Joaquin Delta—					
Fresno	74,800	29,600	7,900	8,600	120,900
Madera	0	0	4,700	8,500	13,200
Merced	235,000	271,300	226,000	240,000	972,300
Mariposa	0	1,400	24,300	122,000	147,700
Stanislaus	287,900	142,600	216,200	15,800	662,500
Tuolumne	0	1,200	20,700	92,500	114,400
Alameda	1,400	1,200	1,400	0	4,000
Contra Costa	25,700	8,300	1,900	100	36,000
San Joaquin	418,500	127,600	83,100	10,000	639,200
Calaveras	700	3,500	49,700	101,500	155,400
Amador	2,900	5,600	16,100	81,100	105,700
El Dorado[1]	300	1,500	34,500	61,600	97,900
Sacramento[2]	19,700	92,700	45,300	4,100	161,800
Totals	1,066,900	686,500	731,800	745,800	3,231,000
San Joaquin Delta—					
Contra Costa	35,000	7,100	200	0	42,300
San Joaquin	186,500	9,500	800	0	196,800
Sacramento[2]	39,500	400	0	0	39,900
Totals	261,000	17,000	1,000	0	279,000
Grand totals	4,214,800	1,755,000	1,524,500	1,004,100	8,498,400

[1] Lands in Cosumnes River Basin only.
[2] Excluding lands in Sacramento Delta and north of Cosumnes River.

Gross Agricultural Areas. Table 17 set forth a summary of the gross areas of agricultural lands in the entire San Joaquin Valley and adjacent foothills, by sections. Class 5 lands are not included in the areas shown in the table since this class is considered as having no portion which will ever be suitable for agriculture.

TABLE 17

GROSS AGRICULTURAL AREAS IN SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS, INCLUDING SAN JOAQUIN DELTA

Section	Gross agricultural area	
	In acres	In per cent of total
Upper San Joaquin Valley floor	4,881,800	57.4
Lower San Joaquin Valley floor	2,360,600	27.8
Foothill areas	977,000	11.5
San Joaquin Delta	279,000	3.3
Totals	8,498,400	100.0

Hydrographic Divisions.

For convenience in carrying on the studies of the utilization of local water supplies tributary to the basin, smaller subdivisions of the areas heretofore described have been made. In general, the boundaries of these subdivisions have been so located as to include lands with a common source of surface supply and for that reason they have been called hydrographic divisions. In areas where no such natural boundaries are indicated, arbitrary lines of division, based upon topography or possible sources of future water supply, have been used. These hydrographic divisions have been numbered from south to north as shown on Plate VI, "Hydrographic Divisions and Zones of Water Service in San Joaquin River Basin."

In the upper San Joaquin River Basin south of the San Joaquin River, the valley floor areas extend practically to the limits of agricultural land. In the lower San Joaquin River Basin, the mountain topography does not descend so abruptly to the valley floor and there are considerable areas of agricultural land which may not soon develop but for which a liberal allowance of local water supply must be made. Many of these lands lie above the stream bed elevations of developed or proposed storage sites. These lands together with rim lands situated below the elevations of the major reservoir sites are designated as foothill lands and have been included in hydrographic divisions having the same number, but with a capital letter appended, as that of the valley division having the same source of local water supply.

Division 1 contains all of the southern end of the San Joaquin Valley floor located in Kern County with the exception of the northerly three miles. The sources of local water supply tributary to this division are the Kern River, that part of the Tejon Creek Group from Franciscan Creek to Tejon Creek, Caliente Creek and the Poso Creek Group excluding White River.

Division 2 consists of that part of the San Joaquin Valley floor located in the northerly three miles of Kern County and in those portions of Tulare and Kings counties south of the Kaweah and Kings River areas of service. The sources of local water supply tributary to this division are the Tule River, Deer Creek and White River of the Poso Creek Group on the eastern side of the valley, and Avenal Creek of the Tejon Creek Group on the western.

Division 3 consists of that part of the San Joaquin Valley floor located in those portions of northern Tulare and eastern Kings County within the Kaweah River area of service. The sources of local water supply tributary to this division are the Kaweah River and the Yokohl and Limekiln Creek groups.

Division 4 consists of that part of the San Joaquin Valley floor located in those portions of Fresno, Kings and Tulare counties within the Kings River area of service. The sources of local water supply tributary to this division are Kings River and Dry Creek.

Divisions 5 and 5B consist of those parts of the San Joaquin Valley floor located west of the Kings River area of service, these divisions being the areas below and above the 350-foot contour, respectively. The sources of local water supply tributary to these divisions are those streams of the Tejon Creek Group lying north of Avenal Creek, Los

Gatos Creek, the Cantua Creek Group, Panoche Creek and Little Panoche Creek in the Orestimba Creek Group.

Division 6 consists of that part of the San Joaquin Valley floor located north and east of the San Joaquin River and south of the Chowchilla River. Division 6A is the adjacent eastern foothill area. The sources of local water supply tributary to these divisions are the San Joaquin, Fresno and Chowchilla rivers, Cottonwood Creek and the Daulton Creek Group.

Division 7 consists of that part of the San Joaquin Valley floor located west of the San Joaquin River, from the vicinity of Mendota on the south nearly to Tracy on the north. The sources of local water supply tributary to this division are the San Joaquin River carrying water contributed by lower east side streams and the Orestimba Creek Group from Laguna Seca Creek on the south to Buenos Aires Creek on the north.

Division 8 consists of that part of the San Joaquin Valley floor located east of the San Joaquin River, north of the Chowchilla River and south of the Merced River. Division 8A is the adjacent eastern foothill area and includes all of the irrigable foothill lands between the Chowchilla River and the northern boundary of the Merced River watershed. The sources of local water supply tributary to these divisions are the San Joaquin and Merced rivers, Dutchman Creek Group, Mariposa Creek, the Owen Creek Group, Bear Creek and the Burns Creek Group.

Division 9 is that part of the San Joaquin Valley floor bounded on the west by the San Joaquin River, on the south by the Merced River and on the north by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and by Dry Creek. Division 9A is the adjacent eastern foothill area within the Tuolumne River watershed, exclusive of lands now receiving a water supply from the Stanislaus River. The sources of local water supply tributary to these divisions are the Tuolumne River and Dry Creek in the Wildcat Creek Group.

Division 10 consists of that part of the San Joaquin Valley floor located south and west of the San Joaquin River Delta and north of Division 7. The sources of local water supply tributary to this division are minor streams in the Orestimba Creek Group north of Buenos Aires Creek. The main water supply for this division is obtained from the delta channels of the Sacramento and San Joaquin rivers.

Division 11 is that part of the San Joaquin Valley floor bounded on the south by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and Dry Creek in the Wildcat Creek Group, on the west by the San Joaquin River and the western boundary of the South San Joaquin Irrigation District, and on the north by Mormon Slough and southern boundary of the Calaveras River watershed. Division 11A is the adjacent eastern foothill area located between the southern boundary of the Calaveras River watershed on the north and Division 9A on the south. The sources of local water supply tributary to these divisions are the Stanislaus River, Wildcat Creek in the Wildcat Creek Group, Littlejohns Creek and Rock, Big Spring and Peachys creeks in the Martells Creek Group.

Gatos Creek, the Cantua Creek Group, Panoche Creek and Little Panoche Creek in the Orestimba Creek Group.

Division 6 consists of that part of the San Joaquin Valley floor located north and east of the San Joaquin River and south of the Chowchilla River. Division 6A is the adjacent eastern foothill area. The sources of local water supply tributary to these divisions are the San Joaquin, Fresno and Chowchilla rivers, Cottonwood Creek and the Daulton Creek Group.

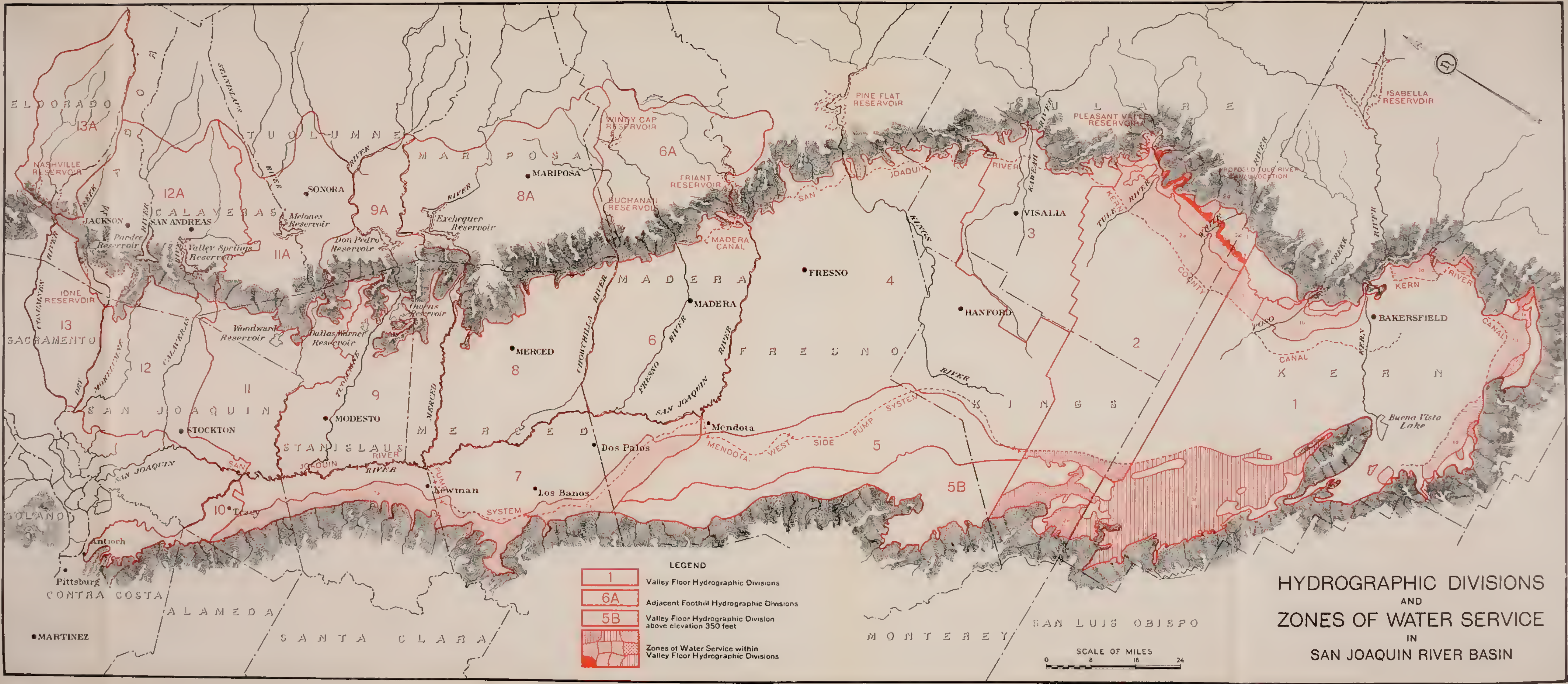
Division 7 consists of that part of the San Joaquin Valley floor located west of the San Joaquin River, from the vicinity of Mendota on the south nearly to Tracy on the north. The sources of local water supply tributary to this division are the San Joaquin River carrying water contributed by lower east side streams and the Orestimba Creek Group from Laguna Seca Creek on the south to Buenos Aires Creek on the north.

Division 8 consists of that part of the San Joaquin Valley floor located east of the San Joaquin River, north of the Chowchilla River and south of the Merced River. Division 8A is the adjacent eastern foothill area and includes all of the irrigable foothill lands between the Chowchilla River and the northern boundary of the Merced River watershed. The sources of local water supply tributary to these divisions are the San Joaquin and Merced rivers, Dutchman Creek Group, Mariposa Creek, the Owen Creek Group, Bear Creek and the Burns Creek Group.

Division 9 is that part of the San Joaquin Valley floor bounded on the west by the San Joaquin River, on the south by the Merced River and on the north by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and by Dry Creek. Division 9A is the adjacent eastern foothill area within the Tuolumne River watershed, exclusive of lands now receiving a water supply from the Stanislaus River. The sources of local water supply tributary to these divisions are the Tuolumne River and Dry Creek in the Wildcat Creek Group.

Division 10 consists of that part of the San Joaquin Valley floor located south and west of the San Joaquin River Delta and north of Division 7. The sources of local water supply tributary to this division are minor streams in the Orestimba Creek Group north of Buenos Aires Creek. The main water supply for this division is obtained from the delta channels of the Sacramento and San Joaquin rivers.

Division 11 is that part of the San Joaquin Valley floor bounded on the south by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and Dry Creek in the Wildcat Creek Group, on the west by the San Joaquin River and the western boundary of the South San Joaquin Irrigation District, and on the north by Mormon Slough and southern boundary of the Calaveras River watershed. Division 11A is the adjacent eastern foothill area located between the southern boundary of the Calaveras River watershed on the north and Division 9A on the south. The sources of local water supply tributary to these divisions are the Stanislaus River, Wildcat Creek in the Wildcat Creek Group, Littlejohns Creek and Rock, Big Spring and Peachys creeks in the Martells Creek Group.


HYDROGRAPHIC DIVISIONS
AND
ZONES OF WATER SERVICE
IN
SAN JOAQUIN RIVER BASIN
LEGEND
1 Valley Floor Hydrographic Divisions
6A Adjacent Foothill Hydrographic Divisions
5B Valley Floor Hydrographic Division above elevation 350 feet
Zones of Water Service within Valley Floor Hydrographic Divisions
SCALE OF MILES
0 8 16 24
ELDORADO
AMADOR
TUOLUMNE
MARIPOSA
CALAVERAS
MADERA
FRESNO
TULARE
KINGS
KERN
MERCED
STANISLAUS
SAN JOAQUIN
SACRAMENTO
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
MONTEREY
SAN LUIS OBISPO
JACKSON
SAN ANDREAS
SONORA
MARIPOSA
MADERA
FRESNO
VISALIA
HANFORD
BAKERSFIELD
MERCED
MODESTO
STOCKTON
Mendota
Dos Palos
Los Banos
Newman
Tracy
Antioch
Pittsburg
MARTINEZ
NASHVILLE RESERVOIR
IONE RESERVOIR
Pardee Reservoir
Valley Springs Reservoir
Melones Reservoir
Don Pedro Reservoir
Exchequer Reservoir
Woodward Reservoir
Dallas Warner Reservoir
Owens Reservoir
WINDY CAP RESERVOIR
BUCHANAN RESERVOIR
FRIANT RESERVOIR
MADERA CANAL
PINE FLAT RESERVOIR
PLEASANT VALE RESERVOIR
ISABELLA RESERVOIR
Buena Vista Lake
MENDOTA-WEST SIDE PUMP SYSTEM
13A
13
12A
12
11A
11
10
9A
9
8A
8
7
6A
6
5
5B
4
3
2
1

80997

Division 12 is that part of the San Joaquin Valley floor bounded on the west by the San Joaquin River Delta north of Stockton and by the main San Joaquin River south of Stockton, on the south by westerly boundary of the South San Joaquin Irrigation District, Mormon Slough and the southern boundary of the Calaveras River watershed, and on the north by Dry Creek of the Sutter Creek Group. Division 12A is the adjacent eastern foothill area located in the watersheds of the Mokelumne and Calaveras rivers and Dry Creek. The sources of local water supply tributary to these divisions are the Calaveras and Mokelumne rivers, Bear and Martells creeks of the Martells Creek Group and Dry and Sutter creeks of the Sutter Creek group.

Division 13 consists of that part of the San Joaquin Valley floor located east of the San Joaquin River Delta, north of Dry Creek and south of the Cosumnes River. Division 13A is the adjacent eastern foothill area within the watershed of the Cosumnes River. The sources of local water supply tributary to these divisions are the Cosumnes River and Willow Creek of the Sutter Creek Group.

Hydrographic divisions 1, 2 and 7 are further divided into zones of water service which are delineated on Plate VI. Hydrographic divisions 1 to 6, inclusive, comprise the upper San Joaquin Valley; and 7 to 13, inclusive, the lower, exclusive of the San Joaquin Delta. The segregation of the classification of valley floor lands, by hydrographic divisions, are set forth in Table 18. The classification of agricultural lands in eastern foothills adjacent to San Joaquin Valley floor is given by hydrographic divisions in Table 19.

TABLE 18

CLASSIFICATION OF LANDS ON SAN JOAQUIN VALLEY FLOOR BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions see Plate VI

Hydrographic division	Gross area, in acres					
	Class					Totals
	1	2	3	4	5	
Upper San Joaquin Valley—						
1	706,100	316,200	310,900	5,600	240,100	1,578,900
2	470,000	231,300	111,800	0	138,000	951,100
3	233,700	102,000	46,000	0	14,500	396,200
4	793,500	237,200	167,500	9,000	164,200	1,371,400
5	304,300	21,000	23,000	0	53,600	401,900
5B	239,200	37,600	8,600	0	25,600	311,000
6	140,100	106,200	104,900	156,100	11,400	518,700
Totals	2,886,900	1,051,500	772,700	170,700	647,400	5,529,200
Lower San Joaquin Valley excluding San Joaquin Delta—						
7	305,700	124,100	63,300	128,900	1,200	623,200
8	114,490	154,100	83,800	85,200	3,400	440,900
9	184,100	134,700	95,700	0	16,900	431,400
10	71,600	10,100	6,200	100	5,300	93,300
11	160,600	106,600	76,800	0	7,400	351,400
12	201,400	50,100	28,400	200	9,300	289,400
13	25,700	94,800	48,500	5,500	0	174,500
Totals	1,063,500	674,500	402,700	219,900	43,500	2,404,100
Totals, San Joaquin Valley floor excluding Delta	3,950,400	1,726,000	1,175,400	390,600	690,900	7,933,300
San Joaquin Delta	261,000	17,000	1,000	0	0	279,000

TABLE 19

CLASSIFICATION OF AGRICULTURAL LANDS IN FOOTHILLS ADJACENT TO SAN JOAQUIN VALLEY FLOOR, BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions see Plate VI

Hydrographic division	Gross area, in acres				
	Class				Totals
	1[1]	2[1]	3	4	
6A	0	0	19,000	[3]58,500 29,100	100,600
8A	0	1,100	[2]7,300 62,500	[3]51,200 105,200	227,300
9A	0	0	[2]22,600 65,000	[3]10,800 35,000	133,400
11A	0	2,400	[2]24,800 49,600	[3]55,500 33,600	165,900
12A	2,700	5,100	62,700	[3]30,700 126,800	228,000
13A	700	3,400	34,600	77,100	115,800
Totals	3,400	12,000	348,100	613,500	977,000

[1] For classes 1 and 2, 80 per cent of gross area is considered irrigable.
[2] Areas for which 50 per cent of gross area is considered irrigable; remainder of Class 3 considered as 60 per cent irrigable.
[3] Areas for which 40 per cent of gross area is considered irrigable; remainder of Class 4 considered as 20 per cent irrigable.

Present Agricultural Development of San Joaquin Valley and Adjacent Foothills.

During the investigations, a survey was made of the present agricultural development of the San Joaquin Valley and adjacent foothills to ascertain the use made of the land and the area under irrigation.

Cropped Areas. A crop survey was made for the purpose of determining the location in which crops of different kinds were grown, the approximate number of acres planted to each of these crops in 1929, and the adaptability of certain areas to the growing of crops of different types. In making this survey, the crops were divided into groups, each of which was designated by a number. The numbers used and the crops represented by them are shown in the following tabulation:

Number *Crop or use of land represented by number*

1. Citrus orchards.
2. Deciduous orchards, including figs and nuts, and olives.
3. Grape vineyards.
4. Grain.
5. Alfalfa.
6. Field crops—under this classification there were included such crops as sorghum, feterita, sudan grass, field corn, maize, etc.
7. Cotton.
8. Irrigated pasture land.
9. Truck crops—including truck gardening, root and bush vegetables and fruits, such as beans, potatoes, sugar beets, melons, strawberries, etc.
10. Rice.
11. Unclassified irrigated areas—probably annuals on the valley floor and small orchards in the foothills.

The crop survey covered substantially the area of land classification, including the area classified from data obtained from previous surveys. No effort was made to grade the crops but their quality was observed as an aid in classifying the land.

Practically every crop grown in California can be found in some part of the San Joaquin Valley and its adjacent foothills. Citrus fruits are grown chiefly in Tulare County in the region adjacent to the eastern foothills between Orange Cove on the north and Terra Bella on the south, in Fresno County in coves adjacent to the foothills between Orange Cove on the south and Fancher Creek on the north and in Kern County in the vicinity of Edison about seven miles east of Bakersfield.

Deciduous orchards, including those of fig and nut trees, are quite generally distributed throughout the eastern side of the valley from the Cosumnes River on the north to Deer Creek on the south, and on the west side from Orestimba Creek north to Antioch. There are smaller scattered areas on the east side of the valley south of Deer Creek in Tulare County and in Kern County.

Grapes of nearly all varieties are grown on scattering areas throughout most of the valley but the largest single area planted to vines is in Fresno and Tulare counties on the Kings River Delta where there is a vineyard area equal to more than half that of the entire valley. Large vineyard areas also are found in San Joaquin, Stanislaus, Merced, Madera, Kings and Kern counties.

In the early days of agriculture in the San Joaquin Valley, grain was the principal crop. As the valley developed and more land was brought under irrigation, portions of the area devoted to grain farming became more valuable for other crops and the areas of grain plantings were considerably reduced. The area still planted to grain, however, is nearly one-third of the entire cropped area of the San Joaquin Valley and approximates twice that of any other single crop. The largest areas are in San Joaquin, Madera, Fresno, Stanislaus, Merced, Kings and Kern counties, but grain is grown extensively in every San Joaquin Valley county. About one-third of all the area planted to grain receives some irrigation.

Alfalfa is found in general throughout the same areas as deciduous orchards and vineyards, the largest areas being located in Stanislaus and Merced counties in the Modesto, Turlock and Merced Irrigation districts. San Joaquin, Fresno, Tulare, Kern, Kings, Madera and Contra Costa counties follow in the order named in the relative size of areas planted to alfalfa.

Field crops which include sorghum, feterita, sudan grass, field corn, maize, etc., are grown in every San Joaquin Valley county. The largest area is found in Kern County, with San Joaquin County second and Fresno County third.

Cotton is grown extensively in all San Joaquin Valley counties south of Merced River. Tulare, Kern and Fresno counties have the largest areas planted to this crop.

The largest single area devoted to the growing of truck crops is located in San Joaquin and Contra Costa counties in and adjacent to the San Joaquin Delta. Areas planted to truck crops also are found in Stanislaus and Merced counties.

A few tracts have been planted to rice during recent years in the lower San Joaquin Valley, principally on the west side of the San Joaquin River between Mendota and Newman, but rice has not become an important crop in the San Joaquin Valley.

Table 20 sets forth the areas of crops under each of the classifications shown in the foregoing list, for that portion of each county in the San Joaquin Valley and adjacent foothills covered by the land classification and crop survey, with the exception of areas in El Dorado and Sacramento counties, which are included in another report.*

The yields and values of agricultural and live stock products from the San Joaquin River Basin and an inventory value of farms, equipment and live stock in the basin are shown in Table 21, by counties. These data were taken mainly from the Fifteenth Census of the United States and no means are available for determining what portion of the products and their values from counties lying only partially within the basin should be credited to other sections. For this reason, no data are included for Sacramento, El Dorado and Alameda counties, the larger part of whose agricultural lands lie outside of the San Joaquin River Basin. To offset the losses on products and values from the portions of these counties lying in the basin, the products and values from portions of Contra Costa and Kern counties which lie outside of the basin are included with those for lands in these counties lying within the basin. It is believed, therefore, that the totals shown for the thirteen counties in Table 21 closely approximate those which would be obtained for the San Joaquin River Basin area only.

For comparison of the agricultural industry in the San Joaquin River Basin with that of the entire State, totals are given in the last column of Table 21 for the yields and values of agricultural and live stock products and the inventory values from farms, equipment and live stock, for the State.

Future Agricultural Development of San Joaquin River Basin.

A study was made to estimate the ultimate water requirements in the San Joaquin River Basin, as explained in Chapter V. In order to estimate these ultimate water requirements, it was necessary to make an estimate of the amounts of land that would be irrigated under the conditions of ultimate development. It was necessary, also, to take into account the marked difference between the upper and lower San Joaquin valleys in the adequacy of local streams to meet the ultimate irrigation demand. The lower San Joaquin Valley is an area in which the local supplies, afforded by the San Joaquin River and its east side tributaries, may be considered plentiful in amount and dependable in occurrence if properly conserved and regulated. It was assumed, therefore, that all of the arable land in this area will be brought ultimately into use and that all lands which are of sufficiently good quality and for which it is physically possible to furnish a water supply will be irrigated. This procedure, also, was followed in estimating the irrigation requirements for lands in the Sacramento River Basin. The upper San Joaquin Valley, on the other hand, is an area in which the tributary run-off is inadequate to meet present requirements and in which ultimate development will be possible only with the importation of waters from distant sources, at relatively high costs. Service under such conditions is only justified for the better lands. In estimating net irrigable areas in each classification the following percentages of gross agricultural areas were used for valley floor lands:

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works, 1931.

S BY COUNTIES, 1929

Area of unirrigated crops, in acres							Total cropped area in acres
2	3	4	5	6	9		
Deciduous and olive orchards	Grape vineyards	Grain	Alfalfa	Field crops	Truck crops	Total unirrigated crops	
0	0	37,900	0	0	0	37,900	239,5C0
0	0	0	0	0	0	0	138,0C0
0	0	0	0	0	0	0	316,900
0	0	96,100	0	0	0	96,100	597,900
0	0	205,000	0	0	0	205,000	288,300
0	0	47,000	0	0	0	47,000	283,300
0	0	0	0	0	0	0	2,900
700	100	22,2C0	1,200	2,300	400	26,900	291,700
----------	0	0	0	0	0	0	3,200
1,000	5,900	165,300	100	5,500	700	178,500	588,800
0	0	1,200	0	0	0	1,200	2,5C0
0	0	3,900	0	0	0	3,900	71,4C0
1,700	6,000	578,600	1,300	7,800	1,100	596,500	2,824,4C0
0	0	0	0	0	0	0	158,0C0
0	0	0	0	0	0	0	36,3C0
0	0	0	0	0	0	0	194,3C0

Table 20 sets forth the areas of crops under each of the classifications shown in the foregoing list, for that portion of each county in the San Joaquin Valley and adjacent foothills covered by the land classification and crop survey, with the exception of areas in El Dorado and Sacramento counties, which are included in another report.*

The yields and values of agricultural and live stock products from the San Joaquin River Basin and an inventory value of farms, equipment and live stock in the basin are shown in Table 21, by counties. These data were taken mainly from the Fifteenth Census of the United States and no means are available for determining what portion of the products and their values from counties lying only partially within the basin should be credited to other sections. For this reason, no data are included for Sacramento, El Dorado and Alameda counties, the larger part of whose agricultural lands lie outside of the San Joaquin River Basin. To offset the losses on products and values from the portions of these counties lying in the basin, the products and values from portions of Contra Costa and Kern counties which lie outside of the basin are included with those for lands in these counties lying within the basin. It is believed, therefore, that the totals shown for the thirteen counties in Table 21 closely approximate those which would be obtained for the San Joaquin River Basin area only.

For comparison of the agricultural industry in the San Joaquin River Basin with that of the entire State, totals are given in the last column of Table 21 for the yields and values of agricultural and live stock products and the inventory values from farms, equipment and live stock, for the State.

Future Agricultural Development of San Joaquin River Basin.

A study was made to estimate the ultimate water requirements in the San Joaquin River Basin, as explained in Chapter V. In order to estimate these ultimate water requirements, it was necessary to make an estimate of the amounts of land that would be irrigated under the conditions of ultimate development. It was necessary, also, to take into account the marked difference between the upper and lower San Joaquin valleys in the adequacy of local streams to meet the ultimate irrigation demand. The lower San Joaquin Valley is an area in which the local supplies, afforded by the San Joaquin River and its east side tributaries, may be considered plentiful in amount and dependable in occurrence if properly conserved and regulated. It was assumed, therefore, that all of the arable land in this area will be brought ultimately into use and that all lands which are of sufficiently good quality and for which it is physically possible to furnish a water supply will be irrigated. This procedure, also, was followed in estimating the irrigation requirements for lands in the Sacramento River Basin. The upper San Joaquin Valley, on the other hand, is an area in which the tributary run-off is inadequate to meet present requirements and in which ultimate development will be possible only with the importation of waters from distant sources, at relatively high costs. Service under such conditions is only justified for the better lands. In estimating net irrigable areas in each classification the following percentages of gross agricultural areas were used for valley floor lands:

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works, 1931.

TABLE 20

CLASSIFICATION OF CROPS IN THE SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS BY COUNTIES, 1929

County	Area of irrigated crops, in acres												Area of unirrigated crops, in acres							Total cropped area in acres
	1	2	3	4	5	6	7	8	9	10	11		2	3	4	5	6	9		
	Citrus orchards	Deciduous and olive orchards	Grape vineyards	Grain	Alfalfa	Field crops	Cotton	Irrigated pasture land	Truck crops	Rice	Unclassified irrigated areas	Total irrigated crops	Deciduous and olive orchards	Grape vineyards	Grain	Alfalfa	Field crops	Truck crops	Total unirrigated crops	
Kern	1,900	8,800	23,600	900	30,400	66,300	64,300	0	4,400	1,000	0	201,600	0	0	37,900	0	0	0	37,900	239,500
Kings	0	12,900	16,300	53,300	21,200	5,500	22,000	6,800	0	0	0	138,000	0	0	0	0	0	0	0	138,000
Tulare	37,100	41,200	75,500	10,100	54,600	12,200	69,500	16,700	0	0	0	316,900	0	0	0	0	0	0	0	316,900
Fresno	2,600	51,400	209,100	0	54,900	37,500	60,500	38,000	1,500	2,800	43,500	501,800	0	0	96,100	0	0	0	96,100	597,900
Madera	0	8,500	25,400	0	17,100	2,000	28,200	1,500	600	0	0	83,300	0	0	205,000	0	0	0	205,000	288,300
Merced	0	29,000	22,200	26,300	69,100	10,700	28,500	20,600	20,100	9,800	0	236,300	0	0	47,000	0	0	0	47,000	283,300
Tuolumne	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2,900	2,900	0	0	0	0	0	0	0	2,900
Stanislaus	50	26,800	26,400	61,300	86,250	9,800	3,600	8,600	39,000	3,000	0	264,800	700	100	22,200	1,200	2,300	400	26,900	291,700
Calaveras, Amador	.....		.....	.....					.....	.....	3,200	3,200	.....	0	0	0	0	0	0	3,200
San Joaquin	0	39,400	64,900	94,600	59,000	34,900	2,300	38,000	77,200	0	0	410,300	1,000	5,900	165,300	100	5,500	700	178,500	588,800
Alameda	0	0	200		1,000	100	0	0	0	0	0	1,300	0	0	1,200	0	0	0	1,200	2,500
Contra Costa	150	13,600	2,100	15,100	8,350	9,500	0	5,000	13,700	0	0	67,500	0	0	3,900	0	0	0	3,900	71,400
Totals	41,800	231,600	465,700	261,600	401,900	188,500	278,900	135,200	156,500	16,600	49,600	2,227,900	1,700	6,000	578,600	1,300	7,800	1,100	596,500	2,824,400
San Joaquin Delta,[1] included in county totals—																				
San Joaquin	0	1,500	0	53,000	15,600	25,500	0	6,300	56,100	0	0	158,000	0	0	0	0	0	0	0	158,000
Contra Costa	0	0	0	13,100	500	8,500	0	4,500	9,700	0	0	36,300	0	0	0	0	0	0	0	36,300
Totals	0	1,500	0	66,100	16,100	34,000	0	10,800	65,800	0	0	194,300	0	0	0	0	0	0	0	194,300

[1] The San Joaquin Delta also includes 24,500 acres of crops irrigated in 1929 in Sacramento County.

80997—Bet. pp. 112 and 113

TABLE 21

AGRICULTURAL STATISTICS OF SAN JOAQUIN RIVER BASIN BY COUNTIES

Item	Unit	Kern	Kings	Tulare	Fresno	Madera	Merced	Mariposa	Tuolumne	Stanislaus	Calaveras	Amador	San Joaquin	Contra Costa	Total for 13 counties	Total for State
Yield of agricultural products in 1929—																
Citrus[1]	Boxes	88,700	0	5,608,000	73,000	300	1,500	600	0	7,000	300	300	300	100	5,780,100	53,803,000
Olives	Tons	215	250	7,519	1,934	224	186	0	0	160	35	3	267	5	10,798	20,800
Orchard fruits[2]	Tons	7,230	26,700	63,730	85,740	9,940	32,370	60	1,200	68,880	370	740	11,940	12,120	321,020	1,139,000
Nuts	Tons	30	20	485	158	27	514	1	4	753	30	9	967	1,110	4,108	42,500
Grapes (fresh basis)	Tons	70,600	49,600	269,000	693,000	51,100	64,800	10	170	65,000	490	1,100	152,000	9,540	1,426,410	1,691,000
Grain[3]	Bushels	370,000	2,322,000	991,000	1,328,000	1,038,000	1,460,000	8,000	13,000	1,892,000	19,000	58,000	4,012,000	780,000	14,341,000	42,367,000
Alfalfa	Tons	92,500	82,000	212,600	195,900	55,800	210,900	100	500	278,700	1,000	2,300	187,600	24,500	1,344,400	2,793,800
Hay and forage crops[4]	Tons	17,000	11,600	45,300	32,100	10,200	27,630	3,400	4,100	40,600	8,200	4,800	66,800	46,100	317,800	1,494,300
Field crop[5]	Bushels	110,300	152,600	147,600	41,400	24,800	85,600	200	500	62,200	1,200	4,100	950,000	216,800	1,797,300	3,171,400
Seed[6]	Bushels	410	270	380	130	0	2,580	0	0	3,940	0	70	63,820	27,400	[illegible]	226,000
Beans and peas (dry)	Bushels	5,770	1,700	1,200	10,700	300	109,500	0	0	462,900	60	920	503,500	10,450	1,107,000	5,589,200
Cotton	Bales	60,300	22,830	61,260	43,730	20,830	16,260	0	0	1,690	0	0	520	0	227,420	253,900
Cotton seed	Tons	28,670	11,270	30,510	21,460	10,030	8,020	0	0	840	0	0	260	0	111,060	124,000
Small fruits[7]	Quarts	99,800	47,100	246,500	391,700	18,500	431,400	8,500	50,300	240,400	8,500	3,600	304,000	16,000	1,866,300	21,736,000
Sugar beets	Tons	0	0	0	0	0	0	0	0	0	0	0	94,820	30,420	125,240	452,800
Potatoes	Bushels	339,600	380	48,860	12,750	5,950	6,100	1,320	2,750	28,230	4,930	3,780	3,817,000	286,300	4,557,950	6,489,000
Cantaloupes and muskmelons	Value in dollars	31,500	1,000	90,700	58,200	3,200	106,700	0	100	648,400	200	200	41,000	11,500	992,700	9,364,000
Tomatoes	Value in dollars	17,500	4,600	35,600	31,200	8,400	173,200	100	1,300	39,400	1,500	900	202,800	543,000	1,059,500	5,481,000
Asparagus	Value in dollars	5,300	200	3,600	71,600	400	9,500	0	0	4,900	0	0	1,195,200	281,600	1,572,300	7,786,000
Celery	Value in dollars	100	0	0	4,000	800	3,500	0	0	43,000	100	0	444,800	1,200	497,500	5,753,000
Dry onions	Value in dollars	57,800	100	17,300	6,700	2,700	14,500	0	600	7,500	300	200	438,600	22,400	568,700	1,831,000
Rice	Bushels	27,700	0	0	141,200	0	389,100	0	0	143,200	0	0	0	24,500	725,700	4,968,000
Yield of live stock products in 1929																
Milk produced	Gallons	6,161,000	14,308,000	28,507,000	18,348,000	6,137,000	31,275,000	172,000	557,000	33,080,000	490,000	759,000	23,428,000	5,360,000	168,582,000	445,530,000
Wool shorn (unwashed)	Pounds	633,000	364,000	202,000	878,000	157,000	397,000	35,000	38,000	431,000	180,000	124,000	327,000	300,000	4,066,000	18,747,000
Honey	Pounds	67,000	73,000	98,000	197,000	42,000	144,000	0	8,100	231,000	1,300	3,900	218,000	39,000	1,122,300	5,476,000
Chicken eggs produced	Dozens	912,000	638,000	3,405,000	2,071,000	509,000	2,259,000	72,000	183,000	4,632,000	67,000	93,000	3,215,000	1,063,000	19,119,000	159,422,000
Chickens sold	Number	101,000	44,000	233,000	169,000	36,000	159,000	4,000	13,000	317,000	12,000	9,000	220,000	82,000	1,399,000	13,861,000
Value of crops and live stock products in 1929—																
Fruits and nuts	In dollars	$2,779,000	$2,482,000	$31,316,000	$22,686,000	$1,770,000	$4,229,000	$8,000	$97,000	$6,194,000	$54,000	$81,000	$6,579,000	$1,532,000	$79,807,000	$296,242,000
Cereals	In dollars	540,000	2,345,000	1,171,000	1,326,000	916,000	1,552,000	6,000	13,000	1,656,000	17,000	54,000	4,102,000	864,000	14,562,000	43,040,000
Other grains and seeds	In dollars	25,000	10,000	9,000	43,000	1,000	438,000	0	0	2,089,000	0	4,000	2,427,000	149,000	5,195,000	28,779,000
Hay and forage	In dollars	1,695,000	1,442,000	3,740,000	3,416,000	985,000	3,523,000	47,000	64,000	4,684,000	124,000	116,000	3,694,000	1,054,000	24,584,000	66,863,000
All other field crops	In dollars	6,284,000	2,384,000	6,364,000	4,555,000	2,089,000	1,700,000	0	0	182,000	0	0	754,000	213,000	24,525,000	30,629,000
Vegetables	In dollars	763,000	46,000	386,000	402,000	78,000	873,000	12,000	32,000	1,399,000	42,000	18,000	7,810,000	1,504,000	13,365,000	71,926,000
Dairy products	In dollars	1,293,000	3,097,000	6,064,000	3,791,000	1,383,000	7,337,000	20,000	98,000	7,683,000	77,000	144,000	5,381,000	1,159,000	37,527,000	96,357,000
Wool shorn	In dollars	171,000	98,000	55,000	237,000	42,000	107,000	10,000	11,000	116,000	50,000	35,000	88,000	84,000	1,104,000	5,192,000
Chicken eggs produced	In dollars	403,000	271,000	1,021,000	978,000	153,000	678,000	24,000	60,000	1,390,000	41,000	51,000	964,000	428,000	6,462,000	51,519,000
Chickens sold	In dollars	101,000	44,000	233,000	169,000	36,000	159,000	4,000	13,000	317,000	12,000	9,000	220,000	86,000	1,403,000	14,699,000
Honey	In dollars	7,000	7,000	7,000	15,000	3,000	11,000	0	1,000	17,000	0	0	16,000	4,000	88,000	523,000
Cattle sold	In dollars	2,027,000	1,024,000	2,494,000	1,782,000	980,000	1,960,000	325,000	303,000	2,049,000	530,000	414,000	1,359,000	682,000	15,929,000	43,808,000
Sheep and lambs sold	In dollars	854,000	370,000	285,000	1,253,000	290,000	484,000	34,000	40,000	456,000	199,000	103,000	740,000	313,000	5,421,000	19,646,000
Hogs sold	In dollars	294,000	238,000	653,000	442,000	189,000	316,000	123,000	66,000	245,000	49,000	76,000	346,000	211,000	3,248,000	14,475,000
Total value	In dollars	$17,236,000	$13,858,000	$53,798,000	$41,095,000	$8,915,000	$23,367,000	$613,000	$798,000	$28,477,000	$1,195,000	$1,105,000	$34,480,000	$8,283,000	$233,220,000	$783,698,000
Inventory value of farms, implements and machinery, and live stock in 1930—																
Land and buildings		$74,497,000	$38,951,000	$151,033,000	$142,982,000	$27,932,000	$68,013,000	$3,265,000	$3,531,000	$97,700,000	$6,316,000	$6,259,000	$138,489,000	$49,590,000	$808,558,000	$3,419,471,000
Implements and machinery		3,101,000	2,248,000	7,484,000	7,275,000	1,518,000	3,492,000	155,000	211,000	5,007,000	265,000	214,000	6,281,000	2,392,000	39,643,000	135,741,000
Domestic animals, chickens and bees		7,007,000	4,251,000	9,727,000	8,974,000	3,569,000	7,967,000	1,018,000	974,000	8,613,000	1,817,000	1,411,000	6,346,000	3,042,000	64,716,000	200,288,000
Total value		$84,605,000	$45,450,000	$168,244,000	$159,231,000	$33,019,000	$79,472,000	$4,438,000	$4,716,000	$111,320,000	$8,398,000	$7,884,000	$151,116,000	$55,024,000	$912,917,000	$3,755,500,000

NOTE. Data compiled from Fifteenth Census of the United States, 1930, except value of cattle, sheep and hogs sold. The value of live stock sold was computed from the live stock inventory and estimate of value of live stock production by California Cooperative Crop Reporting Service.

[1] Grapefruit, lemons, oranges and limes.
[2] Apples, apricots, cherries, figs, nectarines, peaches, pears, plums and prunes, and quinces.
[3] Wheat, oats, barley, rye and mixed grains not separated in harvesting.
[4] Corn silage, timothy, clovers, tame and wild grasses, small grains for hay, legumes for hay and sorghum fodder.
[5] Corn and sorghums harvested for grain.
[6] Grass seeds, clover, alfalfa, sunflower, vetch, flower and vegetable seeds.
[7] Blackberries, loganberries, blueberries, gooseberries, strawberries, raspberries, currants and other fruits.

Class 1	80 per cent
Class 2	80 per cent
Class 3	60 per cent
Class 4	20 per cent

The percentages used for foothill areas have been set forth in Table 19. A higher percentage was used for lands in the delta.

The ultimate net irrigable areas for all classes of land are presented in Table 22 by the same sections as were used in showing the gross agricultural areas in the San Joaquin River Basin, in Table 17. A more detailed tabulation of ultimate net irrigable areas for various classes of land by hydrographic divisions and also an estimate of the net irrigable areas to be served under ultimate development are given in Chapter V.

TABLE 22

ULTIMATE NET IRRIGABLE AREAS IN SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS, INCLUDING SAN JOAQUIN DELTA

Section	Net irrigable area	
	In acres	In per cent of total
Upper San Joaquin Valley floor	3,648,000	61.2
Lower San Joaquin Valley floor	1,676,000	28.1
Foothill areas	380,000	6.4
San Joaquin Delta	257,000	4.3
Totals	5,961,000	100.0

CHAPTER IV

IRRIGATION DEVELOPMENT AND WATER SUPPLY UTILIZATION

Favorable soil and climatic conditions, with the one exception of adequacy of rainfall, have made the San Joaquin Valley a pioneer section in irrigation in California. The development has been rapid and extensive. More than one-third of the total irrigated land of the State lies in the San Joaquin Valley. The irrigated area in the San Joaquin River Basin was over two and one-quarter million acres in 1929. This is about two-fifths of the entire net acreage susceptible of irrigation in that basin.

History of Irrigation Development.

Irrigation development in the San Joaquin Valley began in the decade following 1850 when diversions were made to lands lying adjacent to the streams, although areas of naturally overflowed land had been used for pasturage prior to that time. The lands adjacent to streams had, in many instances, passed into private title as Spanish or Mexican land grants. In later years, additional areas were acquired under various swamp and overflow land acts. The early irrigation developments were largely individual enterprises, some of which have continued in this form to the present time.

Construction of the railroad through the valley during the period 1869 to 1875 resulted in an increase in population and a demand for suitable land for more intensive cultivation. Areas under some of the earlier canals were then subdivided and sold. Additional systems were also built to serve dry sections and bring more land under irrigation. Various forms of organization were used for these enterprises. In some cases, water was sold without participation by the land owner in the ownership of the canal system. This method usually resulted in the canal company becoming a public utility, later subject to regulation in its rates and service. Many of the canals, particularly those of small to medium size, were built through the joint effort of the land owners to be served, under mutual water company forms of organization. While many of these earlier private and mutual water companies still remain in operation, organized developments in recent years have taken the form of irrigation, reclamation and water storage districts. Such districts have, in several instances, absorbed the former public utility systems.

The first California irrigation district law was passed in 1872. It was entitled "An Act to Promote Irrigation" and provided for the formation of irrigation districts by owners of lands susceptible of one mode of irrigation or drainage. All of such owners were required to sign the petition to the county supervisors which initiated the organization, rather than a majority, as provided in later acts. The irrigation district, in the form generally used in the United States, had its origin, however, in the Wright Irrigation District Act, passed by the Legislature of California in 1887.

The early enterprises made use of the natural stream flow only. Due to the rapid reduction in stream flow following the melting of snow on the higher drainage areas, usually in June or early July, the lands which could be given full service without storage were limited. Many areas received only a partial service and either adjusted the crops to those of early maturity, or by excessive use of flood waters, while available, raised the ground water to provide at least partial subirrigation during the remainder of the season. Water logging was often caused by such excessive applications, and continued high ground water resulted in soil injury through alkali accumulations in many areas. Drainage was undertaken in some sections to afford relief.

In the southern or upper valley the first irrigation developments were made by direct surface diversion to lands, principally on the delta fans. For areas distant from streams, where surface supplies were not obtainable, ground water was found to be available and pumping began to be practiced in the early part of the present century. In many localities, where artesian wells first were secured, increased draft has resulted in a lowering of the water table and pumping is now required. Early pumping plants of the steam and gas engine type have been replaced by electrically driven equipment or by modern gas engines. Pumping from wells has been developed to a very large extent in this section of the valley, where stream flow is small in relation to the demand. On the Kings and Kaweah river deltas, pumping from wells, within the irrigated areas, is extensively used to supplement direct surface diversion. For areas further south, practice includes all variations from entire dependence on stream diversion to full pumping or combinations of these two practices.

In the northern or lower valley, direct surface diversions were used until the developments had become sufficiently extensive to enable storage to be financed. These storage developments were made, to a large extent, economically feasible by the development and sale of hydroelectric energy in conjunction with the storage and release of irrigation water. Such storage is now in use on the Merced, Tuolumne and Stanislaus rivers. Pumping from wells is limited to drainage. However, drainage water, in most instances, is re-used for irrigation. On the San Joaquin River, some storage for power is now available as a partial aid to irrigation. Supplies from the lower portions of the San Joaquin River have been obtained by pumping rather than by gravity diversion. This method is used for all west side areas, under irrigation, north of Patterson.

Agencies Furnishing Irrigation Service.

Various forms of organization are used to furnish irrigation service to California lands. They comprise irrigation districts, public utilites, mutual water companes, contract companies, individuals, partnerships, associations, private companies, United States Bureau of Reclamation, United States Indian Service, county water districts, municipal improvement districts, water conservation districts, water storage districts and reclamation districts. Those furnishing service in the San Joaquin River Basin include irrigation districts, public utilities, mutual water companies, water storage districts, a reclamation district, water conservation districts, a county water district, private companies and individuals.

Irrigation Districts—The irrigation district is probably the most important form of organization furnishing irrigation service in California. Districts are formed under the "California Irrigation District Act." The districts have power to issue bonds to pay for their works and to levy and collect taxes, assessments and water tolls to amortize

TABLE 23

IRRIGATION DISTRICTS IN SAN JOAQUIN RIVER BASIN

Active Districts

District	Source of supply	County	Year organized	Area within district boundary, in acres	Area irrigated in 1929, in acres
Alpaugh	Groundwater	Tulare	1915	8,175	5,620
Alta	Kings River	Tulare, Fresno, Kings	1888	129,300	68,450
Banta Carbona	San Joaquin River	San Joaquin	1921	14,379	12,677
Byron-Bethany	Old River	Contra Costa, San Joaquin, Alameda	1919	17,200	10,000
Consolidated	Kings River	Fresno, Tulare, Kings	1921	149,047	129,000
Corcoran	Kings and Kaweah rivers	Kings	1919	51,606	31,820
East Contra Costa	Old River	Contra Costa	1926	20,200	14,939
El Nido	Merced River	Merced	1929	9,450	4,000
Foothill	Groundwater	Fresno, Tulare	1920	50,687	11,000
Fresno	Kings River	Fresno	1920	241,300	192,800
Island No. 3	Kings River	Kings	1921	4,620	3,720
James	Kings River	Fresno	1920	26,266	11,640
Laguna	Kings River	Fresno, Kings	1920	34,858	22,500
Lakeland	Kings and Kaweah rivers	Kings	1923	23,283	4,480
Lemoore	Kings River	Kings	1920	53,100	14,574
Linden	Calaveras River	San Joaquin	1929	13,700	6,000
Lindsay-Strathmore	Kaweah River	Tulare	1915	15,250	7,800
Lucerne	Kings River	Kings	1925	33,407	19,556
Madera	San Joaquin River	Madera	1920	182,000	81,000
Merced	Merced River	Merced	1919	189,682	134,379
Modesto	Tuolumne River	Stanislaus	1887	81,183	66,370
Naglee-Burk	Old River	San Joaquin	1920	2,871	2,057
Oakdale	Stanislaus River	Stanislaus, San Joaquin	1909	74,240	23,321
Riverdale	Kings River	Fresno	1920	15,830	8,640
South San Joaquin	Stanislaus River	San Joaquin	1909	71,112	54,340
Stinson	Kings River	Fresno	1921	11,750	5,984
Terra Bella	Deer Creek	Tulare	1915	12,285	3,933
Tracy Clover	Old River	San Joaquin	1922	1,084	900
Tranquillity	Kings River	Fresno	1918	10,750	6,700
Tulare	Kaweah River	Tulare	1889	34,000	22,350
Turlock	Tuolumne River	Stanislaus, Merced	1887	181,498	133,750
Vandalia	Tule River	Tulare	1923	1,276	1,100
Waterford	Tuolumne River	Stanislaus	1913	14,110	5,079
West Side	Old River	San Joaquin	1915	11,828	11,322
West Stanislaus	San Joaquin River	Stanislaus, Merced	1920	21,400	5,855
Woodbridge	Mokelumne River	San Joaquin	1924	13,851	6,184
Totals				1,826,578	1,143,840

Inactive Districts

District	County	Year organized
El Solyo	Stanislaus	1921
Kasson	San Joaquin	1921
Medano	Madera	1921
Mendota	Fresno	1921
Plainsburg	Merced	1919
Stratford	Kings	1916
Webster	Madera	1916

the cost of, and to operate and maintain their water systems. California irrigation districts are political subdivisions of the State and are organized under the jurisdiction of the county or counties in which they are located. Although it is possible to organize an irrigation district and issue bonds without the approval of the State Engineer, or of the board of supervisors of the county in which the district is located, the bonds are not legal security for public funds and savings banks unless they are certified by the California Districts Securities Commission. The affairs of the district are managed by an elective board of directors, assessor, tax collector and treasurer. A secretary is appointed by the board of directors. The plans for the district must be prepared by a competent irrigation engineer.

There are now 36 active irrigation districts in the San Joaquin River Basin and seven inactive ones. Their histories and statistics are given in detail in other publications.* Of the active districts, only four, the Alta, Modesto, Turlock and Tulare, were in existence prior to 1890. No additional districts were organized until 1909. The period of greatest activity in the formation of these districts was from 1915 to 1925. In 1920, fourteen districts were organized in the State nine of which are in the San Joaquin River Basin. Information on the active districts is given in Table 23.

Public Utilities—A public utility water company is usually a private corporation operating a water system and subject to the provisions of the public utilities act of California and the jurisdiction, control and regulation of the State Railroad Commission. The term also applies to any person, firm or private corporation, their lessees, trustees, receivers or trustees appointed by any court, owning, controlling, operating or managing any water system within the State which sells, leases, rents, or delivers water for compensation to any person, firm, private corporation, municipality, or any other political subdivision of the State. An exception is made in the case of a private corporation or association organized for the purpose, solely, of delivering water to its stockholders or members at cost. Such organization is not a public utility and is not subject to the jurisdiction, control and regulation of the State Railroad Commission. However, a contract water company that sells water to non-contract holders and mutual water companies, delivering water for compensation to others than members or stockholders, becomes a public utility and subject to the jurisdiction of the State Railroad Commission.

The Railroad Commission has power not only to fix rates but also to regulate substantially the entire activities of all public utilities. A public utility water company has no power to levy taxes or assessments against the area it serves, must stand ready to give service if called upon, and may not make any charge unless water service is ordered.

A list of the principal public utility water companies for which data are available in the San Joaquin River Basin, their sources of water supply, the county or counties in which they furnish service and the approximate areas irrigated are given in Table 24.

* Bulletins No. 21, 21-A, and 21-B, "Irrigation Districts in California," Division of Engineering and Irrigation, and Division of Water Resources, State Department of Public Works.

TABLE 24

PUBLIC UTILITY WATER COMPANIES IN SAN JOAQUIN RIVER BASIN, 1929

Name of company	Source of supply	County in which water is served	Approximate area irrigated, in acres
Buena Vista Canal, Incorporated	Kern River	Kern	3,968
Central Canal Company	Kern River	Kern	632
East Side Canal Company	Kern River	Kern	6,053
East Side Canal and Irrigation Company	San Joaquin River	Merced	6,500
Farmers Canal Company	Kern River	Kern	2,890
Foothill Ditch Company	Kaweah River	Tulare	1,800
Kern Island Canal Company	Kern River	Kern	40,610
Kern River Canal and Irrigating Company	Kern River	Kern	2,276
Kings County Canal Company	Tule River	Tulare, Kings	1,203
Lone Oak Canal Company	Last Chance Ditch (Kings River)	Kings	2,000
Madera Canal and Irrigation Company	Fresno River	Madera	6,322
Pacific Gas and Electric Company	Stanislaus River	Tuolumne	1,050
Pioneer Canal, Incorporated	Kern River	Kern	1,908
San Joaquin and Kings River Canal and Irrigation Company, Incorporated	San Joaquin River	Fresno, Merced, Stanislaus	99,419
Stine Canal, Incorporated	Kern River	Kern	6,521
Utica Mining Company	Stanislaus River	Calaveras	466

Mutual Water Companies—A mutual water company, sometimes called "cooperative water company," is any private corporation or association organized for the purpose, solely, of delivering water to its stockholders or members at cost. The stock usually represents physical works and water rights entirely owned by those to be served. Mutual water companies are incorporated under the California statutes regulating the organization of private companies. Many of the mutual companies have been organized as land settlement enterprises. Usually the promoters of the enterprises build the irrigation systems, either wholly or in part, in advance of settlement, organize the mutual companies and issue shares of stock to settlers when the land is sold. In most cases, the settlers obtain control of the mutual company after 50 per cent of the stock has been issued. Some mutual companies have been organized by the landowners directly, working together for the development of a water supply and the construction of an irrigation system. Funds are raised by subscriptions to capital, by direct assessments of capital stock, by bonds and by small loans. In some companies, the stock is appurtenant to the land and may not be separated therefrom. In others, it may be transferred from one owner to another, independent of land ownership. Under this arrangement an irrigator may invest in as many shares as he needs, depending on the crops grown.

The affairs of mutual companies are controlled by a board of directors elected annually by the stockholders. The president is elected by the directors from one of their own number. As a rule the secretary keeps the books and records and computes and collects water charges. A superintendent usually is placed in charge of water delivery, operation and maintenance. A list of the principal organizations for which data are available, considered to be mutual water companies in the San Joaquin River Basin, their sources of supply, the approximate areas irrigated and the county or counties wherein the service areas lie are set forth in Table 25. These data have been obtained from public files, reports, and other available sources and are believed to be fairly reliable.

TABLE 25

MUTUAL WATER COMPANIES IN SAN JOAQUIN RIVER BASIN, 1929

Name of company	Source of supply	County in which water is served	Approximate area irrigated, in acres
Campbell and Moreland Ditch Company	Tule River	Tulare	675
Columbia Canal Company	San Joaquin River	Madera	16,000
Consolidated Peoples Ditch Company	Kaweah River	Tulare	15,500
Crescent Canal Company	Kings River	Fresno and Kings	2,894
Elk Bayou Ditch Company	Kaweah River	Tulare	5,637
Emigrant Ditch Company	Kings River	Fresno	4,500
Empire Water Company	Kings River	Kings	16,000
Evans Ditch Company	Kaweah River	Tulare	2,500
Farmers Ditch Company	Kaweah River	Tulare	8,000
Firebaugh Canal Company	San Joaquin River	Fresno	24,000
First Edison Well Company	Groundwater	Kern	412
Fleming Ditch Company	Kaweah River	Tulare	1,014
Freemont Irrigation Association	San Joaquin River	San Joaquin	649
Goshen Ditch Company	Kaweah River	Tulare	1,867
Hubbs and Miner Ditch Company	Tule River	Tulare	1,059
Jacob Rancho Water Company	Lemoore Canal (Kings River)	Kings	11,013
Jennings Ditch Company	Kaweah River	Tulare	800
Lakeside Ditch Company	Kaweah River	Kings	19,750
Last Chance Water Ditch Company	Kings River	Kings	19,556
Lemon Cove Ditch Company	Kaweah River	Tulare	1,100
Lemoore Canal and Irrigation Company	Kings River	Kings	14,574
Liberty Canal Company	Kings River	Fresno	1,000
Liberty Mill Race Company	Kings River	Fresno	3,870
Lower Tule Water Users Association	Tule River	Tulare	4,259
Mathews Ditch Company	Kaweah River	Tulare	1,150
Melga Canal Company	Kings River	Kings	7,993
Merryman Ditch Company	Kaweah River	Tulare	1,680
Modoc Ditch Company	Kaweah River	Tulare	4,000
Oakes Ditch Company	Kaweah River	Tulare	1,000
Packwood Canal Company	Kaweah River	Tulare	3,000
Patterson Water Company	San Joaquin River	Stanislaus	14,000
Peoples Ditch Company	Kings River	Kings	23,400
Persian Ditch Company	Kaweah River	Tulare	3,500
Pioneer Water Company	Tule River	Tulare	3,012
Poplar Irrigation Company	Tule River	Tulare	3,192
Porter Slough Ditch Company	Tule River	Tulare	1,405
Poso Canal Company	San Joaquin River	Fresno and Merced	20,114
Reed Ditch Company	Kings River	Fresno	3,000
Rhodes and Fine Ditch Company	Tule River	Tulare	437
San Luis Canal Company	San Joaquin River	Merced	40,500
Settlers Ditch Company	Peoples Ditch (Kings River)	Kings	5,300
Second Edison Well Company	Groundwater	Kern	300
Stinson Canal and Irrigation Company	Kings River	Fresno	5,984
Tulare Irrigation Company	Kaweah River	Tulare	3,284
Uphill Ditch Company	Kaweah River	Tulare	1,900
Watson Ditch Company	Kaweah River	Tulare	2,900
Woods Central Irrigating Ditch Company	Tule River	Tulare	1,307
Wutchumna Water Company	Kaweah	Tulare	*7,446

* Exclusive of area in Lindsay-Strathmore Irrigation District.

Water Storage Districts—In general, the purposes of these districts are to store water for irrigation and to distribute water among the owners of lands within their boundaries, in accordance with such priorities in right to water, between the different consumers, as may legally exist. Water storage districts are formed by petition to the State Engineer, rather than to county supervisors, as is the case with irrigation districts. For purposes of carrying out the water storage district act, the Governor is authorized to name two executive directors to assist the State Engineer. A petition for formation must be signed by a majority in number of the holders of title or evidence of title to lands already irrigated, or susceptible of irrigation from a common source and by the same system of storage and irrigation works, and representing a majority in value of said lands; or the petition may be signed by not less than 500 holders of title or evidence of title to lands therein, representing not less than 10 per cent in value of all the lands within the proposed district. The State Engineer determines the practicability, feasibility and utility of the proposed project set forth in such petition. After a hearing by the State Engineer, the matter of organization is submitted by him to an election for majority approval, at which only the holders of title or evidence of title to lands within the district are entitled to vote. The construction of works by a water storage district and the management of the district are under the direction of a board of directors, who have the powers necessary to carry out the purposes of the water storage district act, and may submit propositions relating to the project to the qualified electors at any general or special election. During the construction of works, reports must be filed with the State Engineer.

Four water storage districts have been formed in California, all in the San Joaquin River Basin: San Joaquin River Water Storage District, Kern River Water Storage District, Buena Vista Water Storage District and Tulare Lake Basin Water Storage District. In the case of the San Joaquin and Kern River districts, the objective in organizing was to equitably adjust water rights on San Joaquin and Kern rivers, and to bring about more economic utilization of run-off through the construction and operation of storage reservoirs. The plans of these districts were not consummated. Both were dissolved by due legal process in 1929.

Tulare Lake Basin Water Storage District includes a gross area of 192,730 acres of which 11,520 acres are set aside for reservoir purposes, leaving a net assessable area of 181,210 acres. About 162,000 acres are classed as irrigable, although portions of this area are subject to overflow during years of excessive run-off. The water supply is received from surplus flows of Kings, Kaweah, Tule and Kern rivers. The district includes about twenty reclamation districts and also the Lakeland Irrigation District. With the exception of a small area which projects into Tulare County, north of Alpaugh, the entire district is located in Kings County.

Buena Vista Water Storage District embraces land receiving water from Kern River at the, so-called, "Second Point of Measurement," which is below diversions of the various canals that supply the main portion of Kern River Delta, in the vicinity of Bakersfield. The district boundaries encompass Buena Vista Lake, containing 25,459 acres. This lake, partly used as a storage reservoir and partly farmed, is owned by Buena Vista Reservoir Association, in which Miller and Lux, Inc., hold an 84 per cent interest. The irrigable area in the district, over which assessments have been spread, is 50,405 acres.

Reclamation Districts—Although reclamation districts in California have been formed primarily for the purpose of constructing works to reclaim swamp and overflow lands, some of these districts also have constructed irrigation works. The reclamation district law authorizes the trustees to include in their plans of development such works as may be necessary for irrigation, and gives them the power to adopt rules and regulations for the distribution of water and the establishment and collection of water tolls. In most cases, irrigation within reclamation districts is carried on by individual land owners. However, in some instances the areas are served by mutual water companies.

In other instances, lands in the reclamation district receive irrigation service from irrigation districts. These lands may or may not lie within the irrigation district boundaries. There are many small reclamation districts within the Tulare Lake Water Storage District and on the lower Kings River in Fresno and Kings counties, which are served by that district and organized irrigation districts with flood waters from the Kings, Kaweah and Tule rivers. In the Sacramento-San Joaquin Delta, many of the reclamation districts operate irrigation works. District 2075 (McMullen), organized in 1927 and containing a gross area of 5930 acres, is the only reclamation district in the San Joaquin Valley, above the San Joaquin Delta, operating irrigation works as a district. Water is diverted from the Stanislaus and San Joaquin rivers by means of two main pumping plants, one on each stream.

Water Conservation Districts—There are two laws or statutes in California relating to the organization of water conservation districts. The first of these, known as the "California Water Conservation District Act," was approved in 1923 and amended in 1925 and 1927. This act was drafted primarily to organize the various groups which obtain water from Kings River, for the purpose of storing water on Kings River at the Pine Flat reservoir site, and incidentally for accomplishing an adjustment of the complicated water right situation on that stream. The second act, known as the "Water Conservation Act of 1927," was drafted in the interest of various irrigation companies and irrigators obtaining water from Santa Clara River, in Ventura County, and relates largely to the conservation of water by spreading.

A petition proposing the formation of the Kings River Water Conservation District was filed with the State Engineer June 12, 1924, and an order establishing the sufficiency of that petition was issued July 16, 1924. The principal activity of this district, to date, has been in connection with the establishment of the Kings River water right agreement and monthly diversion schedule. This schedule covers direct-flow rights to Kings River water and its distribution. A second schedule, covering storage rights, is part of the proposed program. The interested irrigation districts and other organized agencies, acting largely through the Kings River Water Association, have made studies pertaining to storage development at Pine Flat.

The Kaweah Delta Water Conservation District was formed for the purpose of conservation and preservation of the underground waters of the Kaweah Delta, together with their sources of supply. The district was organized in 1927 and embraces an area of 259,360 acres in Tulare County and 83,000 acres in Kings County. It is made up of several smaller protective associations, two of which, the St. Johns River Association and the Kaweah River Association, include the Tulare Irrigation District.

County Water Districts—These districts are formed under an act approved June 30, 1913, to which amendments have been made by succeeding legislatures. A large number of such districts have been formed in the State, but mainly for securing domestic water supplies. They are not subject to State supervision and are formed by petition to the county supervisors. Bonds may be issued, when authorized by more than a two-thirds vote of the resident electors, as qualified under the general election laws of the State.

The Stevinson County Water District, located in Merced County at the confluence of the Merced and San Joaquin rivers, was organized in 1930, for the purpose of distributing irrigation water from the San Joaquin River and Deadman, Duck, Owens and Bear creeks and Merced River water to be diverted through the works of the Merced Irrigation District. It includes a small portion of the land now served by the East Side Canal and Irrigation Company, a public utility, and adjacent areas bordering on the San Joaquin and Merced rivers. The total area included in the district is about 7500 acres. Negotiations are now pending for the acquisition of the East Side Canal by the district, together with all right, title and interest of the East Side Canal and Irrigation Company to divert waters of the San Joaquin River and its tributaries, and the waters of several creeks and spillways discharging water from the Merced Irrigation District into the East Side Canal.

Individual and Private Companies—In many cases, individuals, or companies who farm land outside of an organized area, or who have an adequate water supply independent of organized agencies, divert irrigation water from streams by gravity or by pumping, or pump ground water for the irrigation of their own lands.

General Location and Extent of Irrigation Development.

On Plate VII, "Agricultural Lands and Areas Under Irrigation in the San Joaquin Valley and Adjacent Foothills," the total area of agricultural land is shown in yellow and the portion under irrigation development in green. In addition to the areas shown as being under irrigation development, certain lands are used for dry farming. In the San Joaquin Valley, with a small normal rainfall, such farming is confined chiefly to grain.

An inspection of Table 20, in Chapter III, discloses that, of the total area of 2,824,400 acres cropped in 1929, 596,500 acres or 21 per cent were dry farmed. Of the total 2,227,900 acres of irrigated crop lands shown in the table, 1,026,100 acres lie in the lower San Joaquin Valley and adjacent foothills, including delta lands in Contra Costa and San Joaquin counties, but excluding areas in El Dorado and Sacramento counties. The water tributary to this portion of the basin is adequate to support the existing development. The main streams are regulated by storage reservoirs and the lands are adequately served. With these conditions of plentiful water supply, the tendency in the lower San Joaquin Valley is for the irrigated crop areas to increase slightly, year by year. Therefore, it is believed that the figure given for the irrigated lands in the lower San Joaquin is probably the maximum that has been irrigated at any time.

In the upper San Joaquin Valley, the irrigated area, in 1929, was 1,201,800 acres. This total is made up of lands served by surface diversion only, those served by pumping plants only and lands served by both these classes of supply. Due to the low run-off of the 1928–29 season, the irrigated areas for the upper San Joaquin Valley are somewhat below the average. None of the streams, tributary to this portion of the basin, are regulated by surface irrigation storage and the limit of utilization of their surface run-off, under existing diversion

more than a two-thirds vote of the resident electors, as qualified under the general election laws of the State.

The Stevinson County Water District, located in Merced County at the confluence of the Merced and San Joaquin rivers, was organized in 1930, for the purpose of distributing irrigation water from the San Joaquin River and Deadman, Duck, Owens and Bear creeks and Merced River water to be diverted through the works of the Merced Irrigation District. It includes a small portion of the land now served by the East Side Canal and Irrigation Company, a public utility, and adjacent areas bordering on the San Joaquin and Merced rivers. The total area included in the district is about 7500 acres. Negotiations are now pending for the acquisition of the East Side Canal by the district, together with all right, title and interest of the East Side Canal and Irrigation Company to divert waters of the San Joaquin River and its tributaries, and the waters of several creeks and spillways discharging water from the Merced Irrigation District into the East Side Canal.

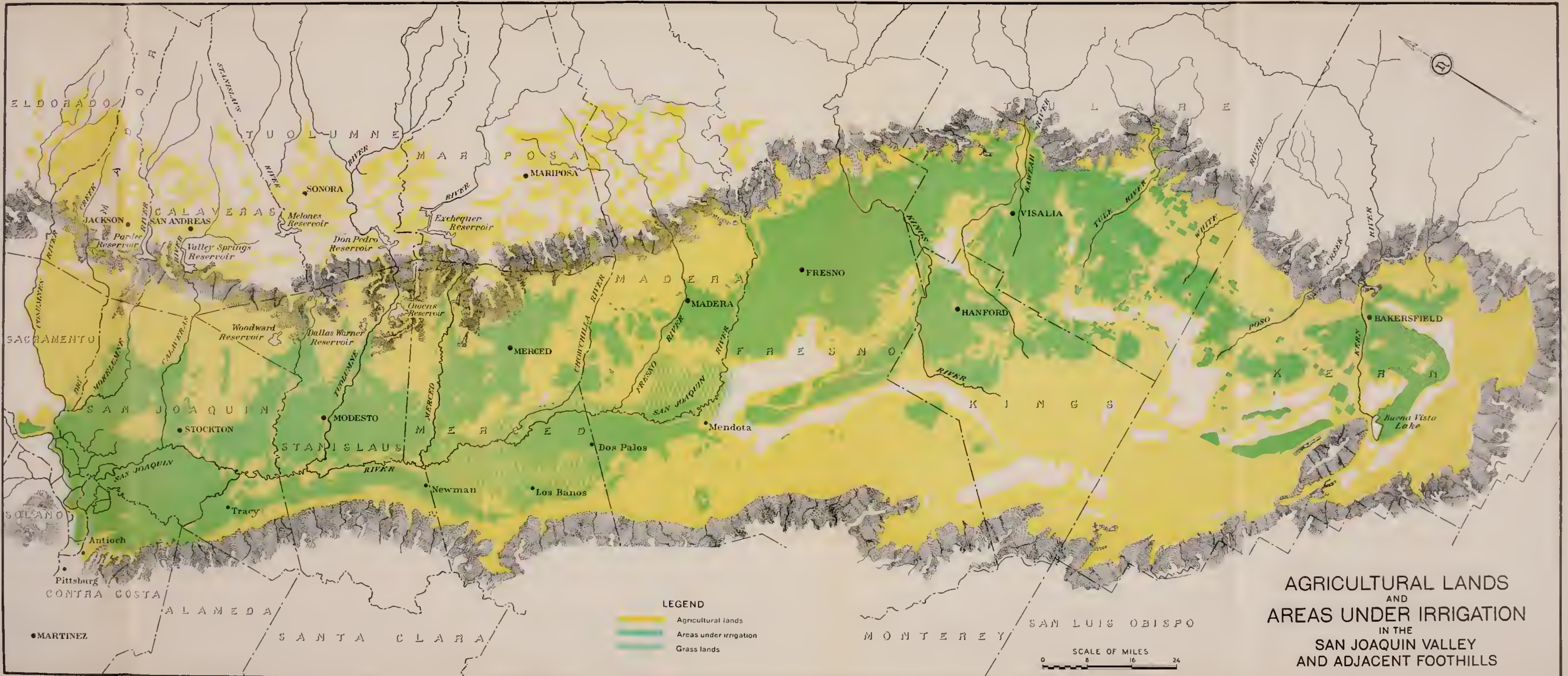
Individual and Private Companies—In many cases, individuals, or companies who farm land outside of an organized area, or who have an adequate water supply independent of organized agencies, divert irrigation water from streams by gravity or by pumping, or pump ground water for the irrigation of their own lands.

General Location and Extent of Irrigation Development.

On Plate VII, "Agricultural Lands and Areas Under Irrigation in the San Joaquin Valley and Adjacent Foothills," the total area of agricultural land is shown in yellow and the portion under irrigation development in green. In addition to the areas shown as being under irrigation development, certain lands are used for dry farming. In the San Joaquin Valley, with a small normal rainfall, such farming is confined chiefly to grain.

An inspection of Table 20, in Chapter III, discloses that, of the total area of 2,824,400 acres cropped in 1929, 596,500 acres or 21 per cent were dry farmed. Of the total 2,227,900 acres of irrigated crop lands shown in the table, 1,026,100 acres lie in the lower San Joaquin Valley and adjacent foothills, including delta lands in Contra Costa and San Joaquin counties, but excluding areas in El Dorado and Sacramento counties. The water tributary to this portion of the basin is adequate to support the existing development. The main streams are regulated by storage reservoirs and the lands are adequately served. With these conditions of plentiful water supply, the tendency in the lower San Joaquin Valley is for the irrigated crop areas to increase slightly, year by year. Therefore, it is believed that the figure given for the irrigated lands in the lower San Joaquin is probably the maximum that has been irrigated at any time.

In the upper San Joaquin Valley, the irrigated area, in 1929, was 1,201,800 acres. This total is made up of lands served by surface diversion only, those served by pumping plants only and lands served by both these classes of supply. Due to the low run-off of the 1928–29 season, the irrigated areas for the upper San Joaquin Valley are somewhat below the average. None of the streams, tributary to this portion of the basin, are regulated by surface irrigation storage and the limit of utilization of their surface run-off, under existing diversion



AGRICULTURAL LANDS AND AREAS UNDER IRRIGATION IN THE SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS

80997

rights, has long since been reached. The cropped land, irrigated solely from surface diversion, varies through wet and dry periods. This is particularly true where lands are in large holdings, as has been the case in Division 1 of this area. On the other hand, the extent of irrigated areas, entirely dependent upon a supply pumped from ground water, has been increasing rapidly even though the water levels underlying these areas have been steadily receding. It is estimated that the acreage so served in 1929 is the maximum of record.

The difference in conditions of present irrigation development, in the upper and lower parts of the San Joaquin Valley, makes a separate discussion of each section essential. In the remainder of this chapter the discussion and maps have been separated into two parts. The first of these deals with the upper San Joaquin Valley, using the same area as that used in Chapter III in discussing agricultural lands. This extends from Chowchilla River on the east side and Mendota on the west side south to the upper limit of the valley. The area from this division northward to the delta and Sacramento Valley areas is discussed under the heading of the lower San Joaquin Valley.

UPPER SAN JOAQUIN VALLEY

Location of Present Irrigation Development.

Practically all present irrigation development is on the east side of the valley and within the valley floor. Water supplies from west side tributaries are inadequate to serve any large area, and ground water is limited in amount and uncertain in quality. Some water from east side tributaries is diverted across the valley trough to lower west side areas along Kern and Kings rivers.

The southern portions of the Sierra Nevada do not contain the same character and extent of foothill lands as occur in the portions adjacent to the lower San Joaquin and Sacramento valleys. The topography is more rough and the soils generally of less depth. There are few mountain valleys of sufficient extent to require consideration in studies of water supplies. The South Fork Valley on Kern River is an exception to this general statement. There are areas of older geologic valley formation, extending from Kern River northward to the vicinity of Porterville, between the valley floor and main mountainous areas, which contain some agricultural lands. These areas, however, have practically no locally tributary water supplies and extend to elevations too great to be considered for service from canals in the valley area. Other cultivated areas, within the foothills, are limited to generally narrow bottom lands along the streams. Broad ridges of tillable land, such as are found in the foothill fruit producing areas further north, do not occur in this general area.

Present Storage.

There are no existing surface reservoirs for irrigation on the streams of the upper San Joaquin Valley, except the relatively unimportant storage in the valley trough on Kern and Kings rivers. Buena Vista Lake stores surplus flood waters of Kern River, for use on lower lands served from that stream. This reservoir is below the main irrigated area on Kern River. Tulare Lake is the depression south of the ridge built across the valley by Kings River, upon which its flow divides, part running north through Fresno Slough to the San Joaquin River and part south to Tulare Lake. Partial reclamation by levees in Tulare Lake restricts the area of overflow, under normal inflow, to smaller areas than those naturally subject to inundation. Water stored in Tulare Lake is used only on adjacent lands below the main areas served from Kings River.

Aside from a relatively small amount on Kaweah River, the existing power storage in the upper San Joaquin Valley is entirely on the San Joaquin River. Much of the water released from this power storage is available for irrigation in the lower San Joaquin Valley. This storage system consists of the reservoirs of the Southern California Edison Company on Big Creek and South Fork, and those of the San Joaquin Light and Power Corporation on the North Fork, comprising a total present constructed capacity of 334,000 acre-feet.

Growth of Irrigated Area.

The growth of irrigation in this area, as a whole, is indicated by the census returns which have been reported by counties, although the county lines do not correspond exactly with the area of the upper valley. The returns for Kern, Tulare, Kings, Fresno and Madera counties represent approximately the area of the upper valley, except that the figures for Fresno and Madera counties include relatively small acreages in the lower San Joaquin Valley. The available data are shown in Table 26. Due to the low seasonal run-off in 1928–29, the figures for irrigated areas tabulated for 1929 are somewhat below the average, as extensive areas normally flooded for pasturage and annuals received no water. The tabular figures indicate the general progress of development. For individual years the acreage is influenced by the volume of run-off, which controls largely the extent of area flooded for pasturage, grain and other annuals.

For the special census of 1902 and the regular censuses of 1919 and 1929, data on irrigated areas have been segregated by stream sources and are shown in Table 27.

TABLE 26

GROWTH OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY BY COUNTIES

County	Area irrigated, in acres				
	From U. S. census of				State crop survey
	1899	1909	1919	1929	1929
Kern	112,533	190,034	223,593	180,106	201,600
Tulare	86,854	265,404	398,662	410,683	316,900
Kings	92,794	190,949	187,868	269,994	138,000
Fresno	283,737	402,318	547,587	533,992	501,800
Madera	23,152	38,705	100,220	140,637	83,300
Totals	599,070	1,087,410	1,457,930	1,535,412	1,241,600

TABLE 27

GROWTH OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY BY STREAM BASINS

Data from U. S. Census reports

Stream	Area irrigated in acres		
	1902	1919	1929
Kern River	116,189	200,641	163,241
Tulare Lake	(1)	70,134	39,804
Tule River	(1)	61,223	74,069
Kaweah River	(1)	149,932	222,363
Kings River	596,091	552,601	742,282
Fresno River	10,729	12,414	17,640
Totals	723,009	1,046,945	1,259,399

[1] Not reported separately; included with Kings River.

Information on the use of underground water in the upper San Joaquin Valley is also available from the census returns. Data are available for the years 1919 and 1929 on the capacities of flowing and pumped wells and are set forth in Table 28. These data clearly indicate the rapid growth of pumping in that region and the decrease in capacities of artesian wells through expansion in the use of underground water.

TABLE 28

CAPACITY OF WELLS IN UPPER SAN JOAQUIN VALLEY, FOR 1919 AND 1929, BY STREAM BASINS

Data from U. S. Census reports

Stream	Flowing wells, capacity in gallons per minute		Pumped wells, capacity in gallons per minute	
	1919	1929	1919	1929
Kern River	13,850	1,475	219,674	893,789
Tulare Lake	8,253	0	434,565	48,735
Tule River	251	0	493,272	565,316
Kaweah River	17	0	842,085	1,884,312
Kings River	10,000	950	1,183,710	5,698,807
Fresno River	200	0	79,255	162,675
Totals	32,571	2,425	3,252,561	9,253,634

The aggregate capacity of the flowing and pumped wells in 1919, for the whole area, was about 7300 second-feet or 440,000 acre-feet per month, if operated continuously. The corresponding values for 1929 were 20,600 second-feet and 1,240,000 acre-feet, respectively. The capacity figure, of 440,000 acre-feet per month for 1919, is about equal to the average total stream flow in June for the major streams south of San Joaquin River for the 10-year period, 1919–1929, and the capacity figure 1,240,000 acre-feet per month for 1929 is about three times that stream flow. The capacity figure for 1919 is about four times and that for 1929 about twelve times the average stream flow for July and August for the same period. These figures indicate the dependence of the upper San Joaquin Valley on ground water for its present development.

Present Irrigated Crops.

A comprehensive survey of the extent and character of crops irrigated in this area was made in 1929 as a part of the investigations on which this report is based. The results for local areas are presented with the description of the details of each local area. For the entire area of the upper San Joaquin Valley, the results of this survey of irrigated crops are summarized in Table 29. Due to the low run-off of the season 1928–29, the irrigated acreages given in the tabulation are somewhat below the average.

TABLE 29

IRRIGATED CROPS IN UPPER SAN JOAQUIN VALLEY, 1929

Crop	Area irrigated in 1929, in acres
Citrus	41,600
Deciduous and olives	122,600
Grapes	349,700
Grain	64,300
Alfalfa	174,200
Field	123,000
Cotton	212,500
Irrigated pasture	62,900
Truck	6,500
Rice	1,000
Unclassified	43,500
Totals	1,201,800

The data in the foregoing table illustrate the wide variety of crops which are produced in the upper San Joaquin Valley. Agricultural practice varies from the highest types of citrus culture to the crude overflow pasture area. Practice has been adjusted to the varying climatic, soil and water supply conditions of the different parts of the area. Citrus fruits are grown along the eastern edge of the valley on areas high enough to be relatively free from frost. Such areas extend southerly from the Kings River area, but the development is not continuous. The necessary favorable conditions of soil, temperature and water supply are not present in all parts of the area. The largest citrus developments occur adjacent to the eastern foothills, from the Kings River south to Deer Creek. Grape vineyards are prevalent throughout the area. They are devoted to the culture of raisin, wine, and table varieties. A large percentage of the raisins produced in the United States is grown in this area. Deciduous fruits comprise nearly all of the commercial varieties, including peaches, apricots, prunes and figs. Alfalfa is grown both for local use, largely in dairying, and for shipment. The long growing season results in large yields, where an adequate water supply is available. A wide variety of annual crops is produced. In 1929, cotton was the irrigated annual crop of largest acreage. The area in cotton varies with price conditions and has declined since 1929. Truck crops are grown more extensively in the southern portion of the area which is nearer to the Los Angeles market. Grain is irrigated in areas of uncertain water supply, when water is available, as it is better adapted to such conditions of irregular service than other crops. It is extensively grown in Tulare Lake Basin. In addition to the area of irrigated grain shown in Table 30, there were

319,000 acres of dry farmed grain in the upper San Joaquin Valley in 1929.

Ground Water Conditions.

While little surface storage for irrigation has been constructed in this area, extensive use has been made of ground water storage. For the conditions existing in many parts of the area this has been an economical type of development.

Prior to the settlement of the valley, all of the tributary water supply either ran off through existing channels or overflowed on adjacent lands. Drainage to the lower valley was retarded by the barrier built by Kings River, and run-off from streams south of the Kings could reach the San Joaquin River only after filling Tulare Lake. Run-off was dissipated by evaporation from Tulare Lake or other water areas, by transpiration of the tule and grass growths on overflowed lands and, in years of extremely large run-off, by overflow to the north into the San Joaquin River. Kern River built a smaller ridge at the southern end of the valley with two depressions on its south side, Kern and Buena Vista lakes, which functioned for Kern River similarly to Tulare Lake for Kings River. The only ground water records for this period are general in character. Lands near streams and overflow areas had generally high ground water. Areas back from streams generally had depths to ground water greater than the limits of plant use. Illustrations of this are the depths of 50 to 60 feet to ground water near Fresno and similar depths at Rosedale and other areas north of Kern River. Absorption from higher overflow areas or stream channels reached lower areas under confining strata and resulted in artesian pressures in the valley trough. Such artesian areas extended into the lower portions of the stream deltas.

Following the construction of canal systems into areas away from stream channels, artificial sources of ground water were made available. Seepage from canals and percolation from lands resulted in raising the ground water until, in many areas, it came within reach of the crop roots and close enough to the ground surface to result in water logging and alkali concentrations. Such injured lands generally reverted to pasture use.

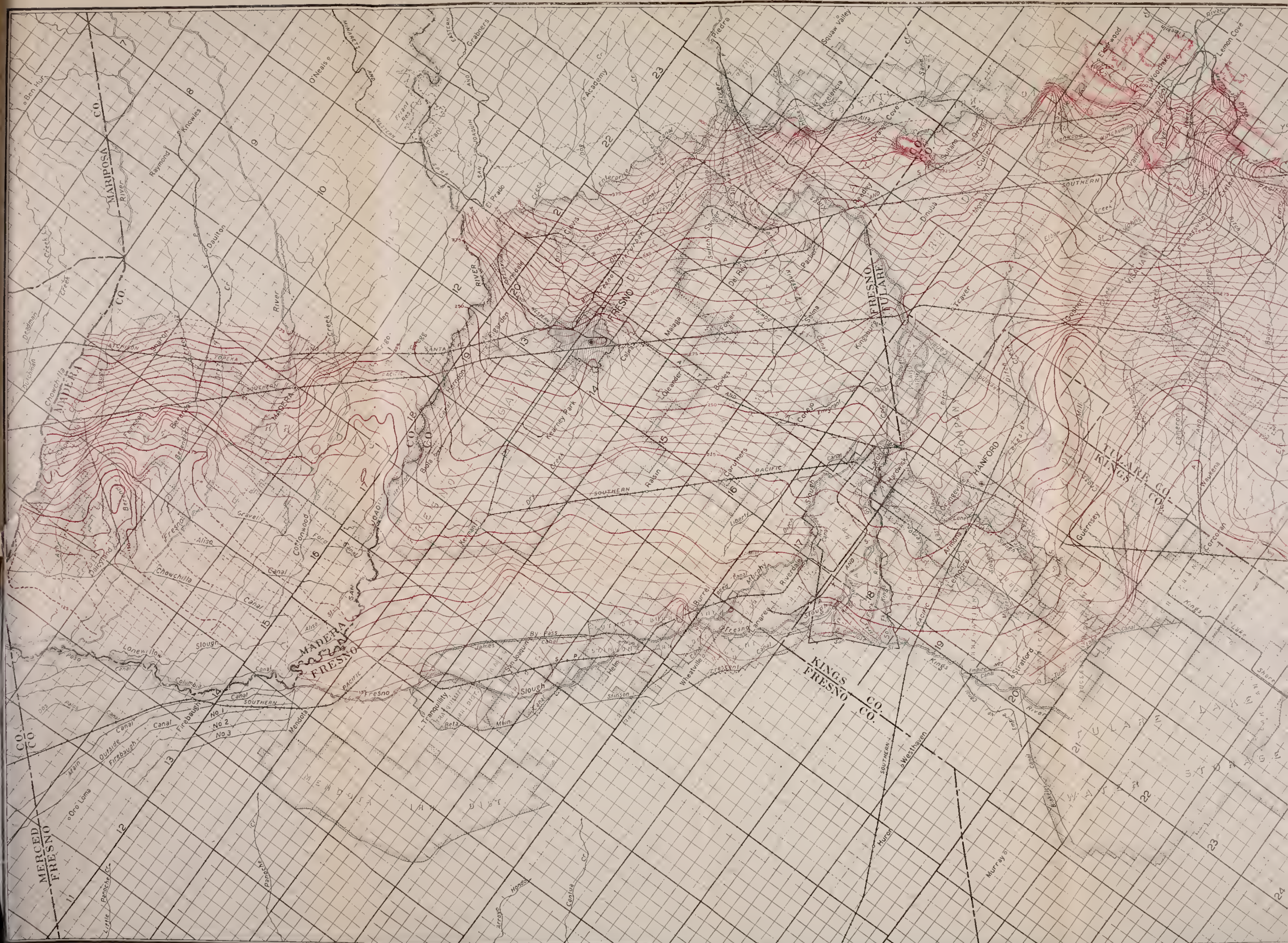
When surface diversions had utilized the available stream flow, ground water developments were begun. Among the earlier developments were attempts to use artesian flow near Semitropic, in Kern County, and pumping for citrus orchards near Lindsay. The loss of artesian pressure and difficulties with soils resulted in a general decline of pumping near Semitropic. The limited local replenishment, in the area near Lindsay, resulted in lowering and change in quality of the ground water, so that it became necessary to seek an outside water supply. The demand for land, in the period from 1900 to 1910, resulted in the undertaking of pumping from wells in many parts of the area. Such developments waited until land values had increased to a point where pumping costs could be supported. Electric power became available for pumping and the growth of ground water use has been continuous to date. Pumping plants have been installed in areas having no surface supply and in canal-served areas for supplemental use.

The extension of pumping in recent years has altered ground water conditions in many irrigated areas. Instead of losses from canal use causing an injuriously high ground water table, pumping drafts have exceeded replenishments and recessions have occurred. Recessions in some areas have been of benefit in supplying needed drainage. In areas of inadequate surface supplies, the draft has exceeded the replenishment and progressive recession is taking place. Such recession increases the pumping lift and costs. The subnormal run-off of recent years has aggravated this condition. In areas dependent entirely on pumping and without active local sources of ground water supply, the success obtained from the operation of the earlier plants has resulted in stimulating additional development until overdraft has occurred. The resulting recession has proceeded in some areas to a point where the cost of the increased pumping lifts exceeds the value of the use on some crops.

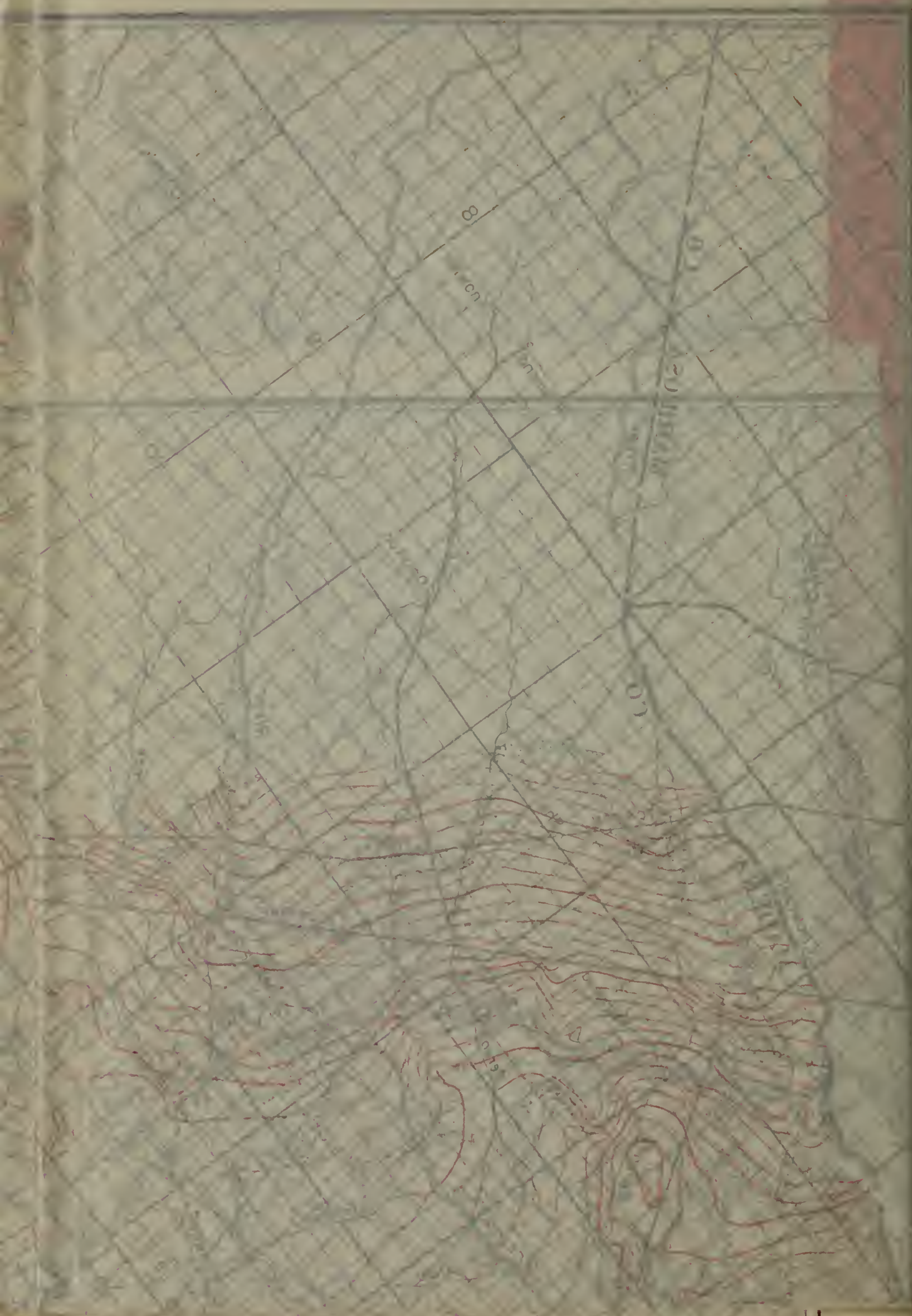
The conditions vary so widely in the different local areas that generalizations or averages are of limited assistance only in studying the problems of the upper San Joaquin Valley. A study of ground water conditions in each local area is necessary for a determination of present needs. It is also necessary for the formulation of any plans for the relief of present overdrafts, as ground water storage is an essential part of the plans for such relief. For the purpose of making this study, the area under consideration has been subdivided into smaller areas, designated as ground water units. The boundaries of these units were determined by local conditions of influence upon ground water. The analyses and conclusions regarding amounts of deficiencies are given in Chapter VIII. In the following discussion the records and results regarding past experience in the use of ground water are described, because they are more conveniently discussed with the descriptions of the canal systems in the different local areas. Some features regarding ground water conditions of the valley can be shown for the area as a whole. This has been done on general plates. Other features, applicable to local areas only, are shown on plates described with the discussions of such local areas or units.

Plate VIII, "Lines of Equal Elevation of Ground Water Table in Upper San Joaquin Valley, Fall of 1929," is based on measurements on about 1700 wells distributed throughout the area. Lines of equal elevation shown in red are referred to U. S. G. S. datum. This plate indicates the direction and rate of ground water slope for the area as a whole. The general ground water slope is from the east side of the valley toward the valley trough. Ground water cones are built up under the deltas formed by some of the streams. The effect of excessive ground water draft in some local areas is shown in the resulting ground water depressions.

Sufficient data were not available to plot lines of equal elevation for the Tulare Lake area, which is here used to include the total area of the Corcoran and Lakeland districts and the Tulare Lake Water Storage District, served by water diverted from the Kings, Kaweah and Tule rivers, mainly at high stages. Ground water supplies in this area are obtained mainly from the deeper strata and artesian wells formerly were obtainable. The formation is considered relatively non-absorptive and a definite natural barrier along the eastern rim seems


MARIPOSA CO.
MADERA CO.
FRESNO
MADERA
TULARE
HANFORD
KINGS CO.
FRESNO CO.
TULARE CO.
MERCED CO.
Clovis
Sanger
Selma
Kingsburg
Dinuba
Visalia
Lemoore
Armona
Riverdale
Raisin
Malaga
Fowler
Kearney Park
Oleander
Bowles
Caruthers
Firebaugh
Mendota
Tranquillity
Huron
Westhaven
Stratford
Corcoran
Guernsey
Waukena
Lemon Cove
Woodlake
Squaw Valley
Piedra
Academy
Friant
Raymond
Knowles
Daulton
Berenda
Chowchilla
Dairyland
Oro Loma
Ben Hur
O'Neals
Traver
Orosi
Cutler
Exeter
Grangeville
Hardwick
Laton
Conejo
Burrel
Oleander
Murray
SOUTHERN PACIFIC
ATCHISON TOPEKA AND SANTA FE
SAN JOAQUIN RIVER
Kings River
Chowchilla Canal
Fresno Slough
Lone Willow Slough
Outside Canal
Main Canal
Little Panoche Cr.
Panoche Cr.
Cantua Cr.
Arroyo Hondo

LINES OF EQUAL ELEVATION OF GROUND WATER TABLE IN UPPER SAN JOAQUIN VALLEY FALL OF 1929



to resist ground water movement into the area from the east. The depth to ground water in a few scattered wells measured in 1929 was about 100 feet, as compared with that of 30 feet in the area just east of Corcoran on the outer Tule Delta.

Among the areas in which the result of excessive ground water draft is shown on Plate VIII are the Edison and Arvin areas, the marked cone of depression near Delano, the smaller cone at Earlimart, the extensive cone surrounding Lindsay and small local depressions in the Madera area. Other areas, in which the draft has resulted in ground water lowering, without having as yet resulted in a closed cone of depression, are in the vicinity of Shafter, Wasco and McFarland in Kern County, west of Tulare and Goshen, within the city of Fresno and in parts of the Madera Unit.

The effect of stream flow in building up the adjacent ground water is illustrated by the ground water contours near Kern River and in the upper portions of Tule and Kaweah deltas. Ground water slopes toward Kings River where it is in a depressed channel through Centerville Bottoms. Below Kingsburg the river is on a slight ground water ridge. The San Joaquin River where it enters the valley flows in a relatively deep channel. On the south side of the river, irrigation in the Fresno Irrigation District with surface supplies from the Kings River has resulted in a ground water table sloping toward the river. On the north side, pumping without canal service in the Madera area has resulted in a slope away from the river.

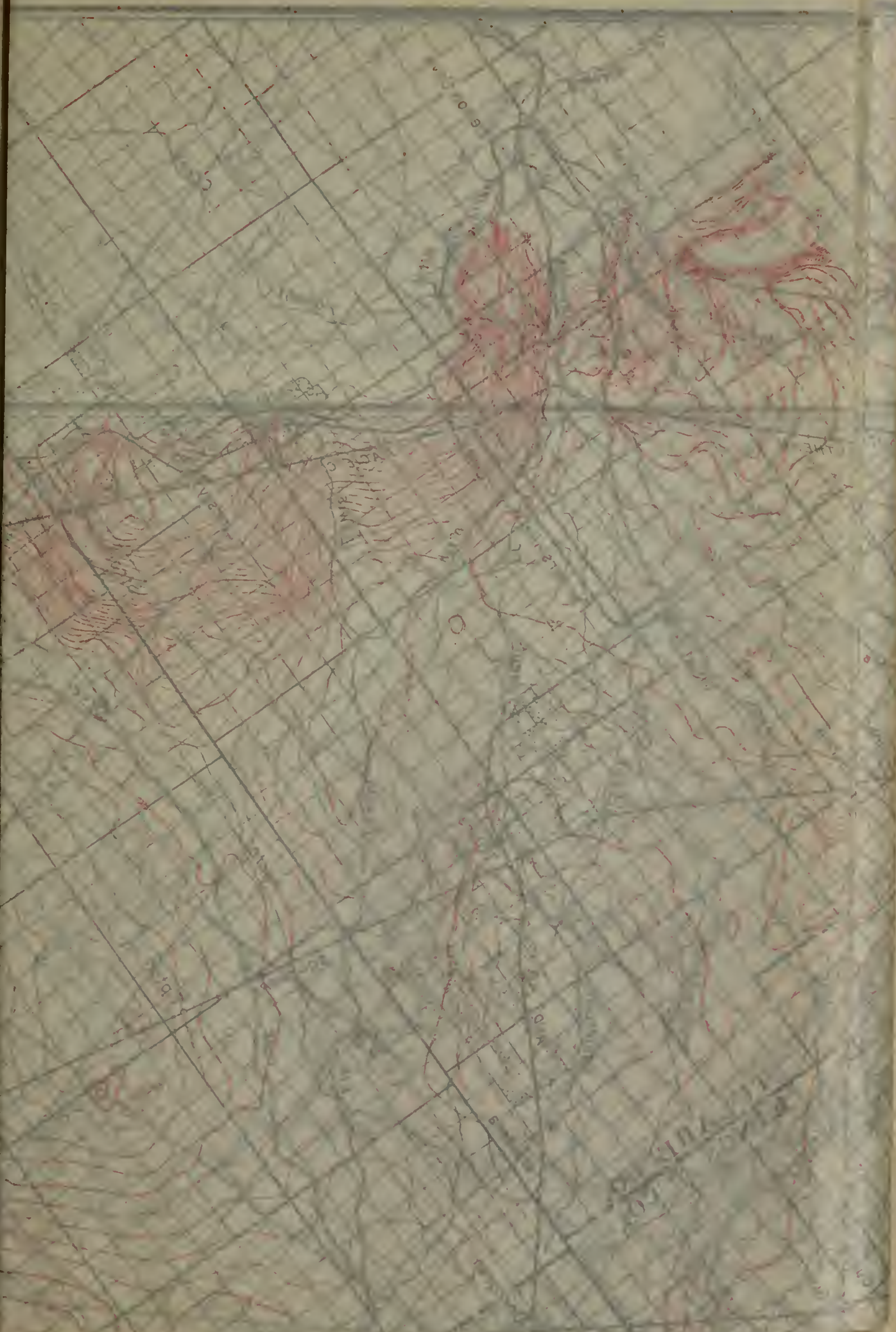
Plate IX, "Lines of Equal Depth to Ground Water Table in Upper San Joaquin Valley, Fall of 1929," shows the difference in elevation between the ground water contours delineated on Plate VIII and the ground surface. These lines are shown in red. The depth to ground water as shown on the plate plus the drawdown while pumping would represent the total pumping lift to ground surface at a particular location. The drawdown during pumping depends on the tightness of the water bearing materials and the rate of pumping draft. For the usual rates of pumping, drawdowns in the more open materials vary generally from ten to 25 feet and for the finer materials drawdowns of from 25 to 50 feet may occur. Plate IX also brings out the effect of excessive pumping on the depth to ground water. Like Plate VIII it is based on measurements of about 1700 wells. While the depth increases from the valley trough toward the eastern side of the valley, local increases in depth are shown in areas of heavy pumping draft away from direct sources of water supply. The rapid increase in depth to ground water in the Arvin area is due to the rise in ground elevation over a relatively flat ground water slope. The same conditions occur in the higher valley areas north of Kern River and in southern Tulare County. The effect of canal service in maintaining a relatively high ground water table is shown in the main canal served areas on Kern and Kings rivers where depths of from five to ten feet occur over large areas, with additional areas having depths of from ten to 20 feet. These relatively shallow depths, shown on Plate IX for 1929, obtain immediately following a series of years of less than normal run-off. Similar lines for 1921 would show much larger areas having ground water within ten feet of the ground surface. The effect of heavy pumping draft in increasing the pumping lift is shown clearly for areas in the vicinities of Delano, Lindsay, Tulare, Goshen and south of Madera and west of Chowchilla. The depth to ground water in these areas is greater than that in similar adjacent areas of smaller pumping draft.

Plate X, "Lines of Equal Total Lowering of Ground Water Table in Upper San Joaquin Valley, 1921–1929," shows the total lowering of ground water that has occurred in the eight-year period for those parts of the area for which records are available. These lines of equal total lowering, shown in red and based on measurements on wells varying in number from about 900 in 1921 to about 1700 in 1929, were interpolated from differences in elevation of ground water estimated for each section corner from the 1921 and 1929 ground water elevations. This plate brings out, even more forcibly than Plates VIII and IX, the large variation in lowering in different areas. The amount of lowering is generally proportional to the distance from direct sources of ground water supply and the extent of pumping draft. Maximum lowering of 85 feet is shown for the Lindsay area which is distant from sources of supply and with large areas irrigated by pumping. Lowering of 70 feet is shown at Delano. The lowering for other areas of heavy pumping draft varies generally from 25 to 50 feet where no direct sources of water supply are available. In other areas of extensive pumping which have direct sources of water supply, such as the areas under the upper Kings River canals, parts of the Kaweah Delta and the main canal served areas on Kern River, lowering of from five to ten feet has occurred. Although the stream flow for the period, 1921–1929, has been below normal, there are some areas in which no lowering has occurred. These are relatively small in extent, however, and occur along stream channels.

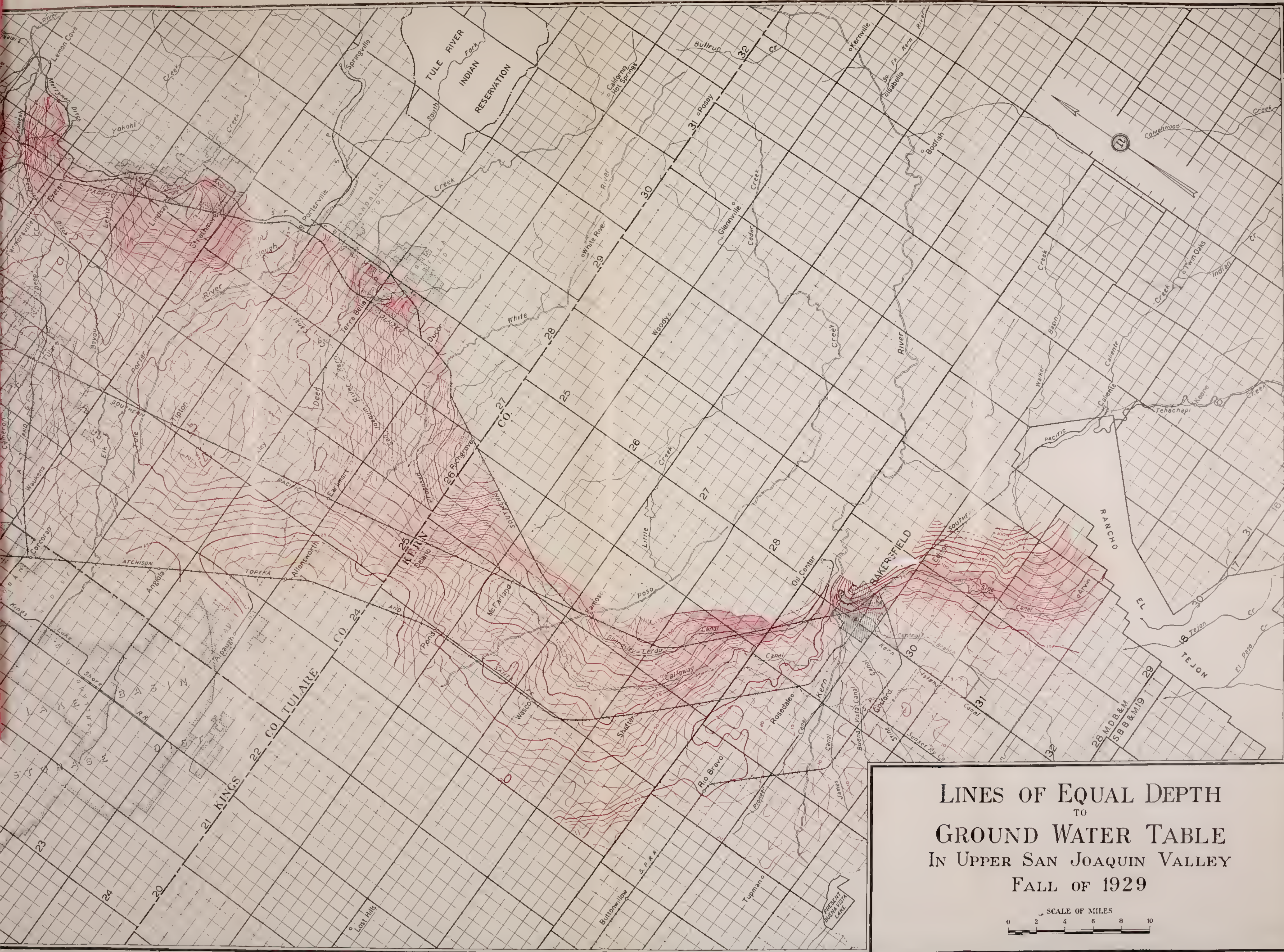
On Plate XI, "Zones of Variation in Depth to Ground Water, San Joaquin Valley, Fall of 1929," are shown by zones, the depth to ground water, between given limits, in both the upper and lower San Joaquin valleys. Areas having depths of less than ten feet are generally adjacent to streams or in canal served areas where little pumping for irrigation is practiced. Depths to ground water are generally less in the lower San Joaquin Valley than in the upper. Much of the canal served area in the upper San Joaquin Valley has depths of from ten to 25 feet. Outside of the canal served areas, depths are generally from 50 to over 200 feet.

Ground water profiles and hydrographs of the records of fluctuation of typical wells have been prepared. The locations of these profiles and wells are shown on Plate XII, "Key Map Showing Boundaries of Ground Water Units and Locations of Profiles and Typical Record Wells, Upper San Joaquin Valley."

Plate XIII, "Profiles of Water Levels in Ground Water Units of Upper San Joaquin Valley Along Line X-X, 1921 and 1929," shows the general ground surface and ground water levels through all ground water units from Chowchilla River to the vicinity of Arvin. This plate also illustrates the varying effect of factors of draft and supply. In general, the ground water is close to the ground surface near the main stream channels and has shown little lowering in their vicinity during the eight-year period. This is well illustrated in the Madera




MERCED CO.
FRESNO CO.
MADERA CO.
MARIPOSA CO.
FRESNO
MADERA
TULARE
TULARE CO.
KINGS CO.
FRESNO CO.
KINGS CO.
HANFORD
VISALIA
Ben Hur
O'Neals
Knowles
Raymond
Daulton
Academy
Friant
Grabners
El Prado
Clovis
Trigo
Gregg
Biola
Kearney Park
Oleander
Malaga
Bowles
Caruthers
Raisin
Kerman
Chowchilla
Fairmead
Berenda
Sharon
Dairyland
Gravelly
Alsino
Cottonwood
Fresno
Mendota
Firebaugh
Tranquillity
Helm
Stinson
Wheatsville
Riverdale
Laton
Kingsburg
Selma
Del Rey
Parlier
Reedley
Sanger
Dinuba
Sultana
Cutler
Orosi
Monson
Traver
Goshen
Elderwood
Woodlake
Lemon Cove
Seville
Yokohl
Navelencia
Squaw Valley
Piedra
Orange Cove
Grangeville
Armona
Lemoore
Stratford
Guernsey
Corcoran
Waukena
Westhaven
Huron
Murray
Oro Loma
Hardwick
Lonewillow
Columbia
Dos Palos
SANTA FE
SOUTHERN PACIFIC
Canal
Slough
By-Pass
Kings River
San Joaquin River
Chowchilla Canal
Tulare Lake
Cameron
Elk Bayou
Deep Cr.
Panoche Cr.
Cantua Cr.
Arroyo Hondo
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24



LINES OF EQUAL DEPTH TO GROUND WATER TABLE IN UPPER SAN JOAQUIN VALLEY FALL OF 1929

MARIPOSA CO.
MADERA CO.
MADERA
FRESNO
FRESNO CO.
TULARE
TULARE CO.
KINGS CO.
KINGS CO.
FRESNO CO.
MERCED CO.
FRESNO CO.
MADERA
FRESNO
HANFORD
VISALIA
Clovis
Reedley
Dinuba
Selma
Kingsburg
Fowler
Sanger
Del Rey
Parlier
Malaga
Oleander
Bowles
Conejo
Caruthers
Raisin
Kerman
Herndon
Biola
Kearney Park
Laton
Hardwick
Grangeville
Armona
Lemoore
Stratford
Guernsey
Corcoran
Traver
Goshen
Lemon Cove
Woodlake
Elderwood
Orange Cove
Squaw Valley
Piedra
Academy
Friant
El Prado
Trigo
Gregg
Berenda
Fairmead
Chowchilla
Dairyland
Sharon
Daulton
Raymond
Knowles
O'Neals
Ben Hur
Mendota
Firebaugh
Tranquillity
Helm
Riverdale
Burrel
Murphy
Wheatville
Westhaven
Huron
Murray
Oro Loma
Cameron
Waukena
Tulare Lake
SANTA FE
SOUTHERN PACIFIC
ATCHISON TOPEKA AND SANTA FE
FRESNO IRRIGATION DIST.
ALTA IRRIGATION DIST.
KINGS RIVER
SAN JOAQUIN RIVER
Fresno Slough
Chowchilla Canal
Lone Willow Slough
Outside Canal
Main Canal
Columbia Canal
By Pass Canal
Stinson Canal
Crescent Canal
Liberty Canal
Last Chance Ditch
Lakeside Ditch
Cottonwood Creek
Dry Creek
Kaweah
Tule
Panoche Cr
Little Panoche Cr
Cantua Cr
Arroyo Hondo

80997

LINES OF EQUAL TOTAL LOWERING OF GROUND WATER TABLE IN UPPER SAN JOAQUIN VALLEY 1921 - 1929

Unit, where greater depth and lowering are shown in the areas away from stream channels. The relatively deep channel of the San Joaquin River is shown clearly. This causes the slope of the ground water in the northern portion of the Fresno Irrigation District to be toward the San Joaquin River. Shallow depth, with relatively small lowering, is shown generally in the main Kings River area, crossed by the profile. The profile crosses the Kaweah Delta in its outer portion where the stream is divided among several channels. Cross Creek is the only one of these channels under which the conditions in adjacent areas have supported a relatively high ground water table. Cross Creek is approximately the dividing line between the deltas of Kings and Kaweah rivers. Flows in the portions of Mill, Packwood and Cameron creeks crossed by the profile are not sufficient in amount or in regularity of occurrence to maintain high ground water under present conditions of draft. Tule River and Deer Creek do not show any effect on the adjacent ground water. Profile X-X crosses both of these channels below the point to which regular flow extends. There are no streams of importance, tributary to the area crossed by the profile, from Tule River to Kern River. There are, however, relatively large areas dependent on ground water pumping. The result is clearly shown by the differences in elevation between the ground water profiles for 1921 and 1929. In the Rosedale area near Kern River the depth to ground water is less and, due to the stream flow and canal use, little lowering has occurred. South of Bakersfield Profile X-X crosses the higher ground on the point of the Kern River Bluffs. This causes increased elevation of the ground surface profile. Such increase in ground surface elevation is not reflected, however, in the ground water profiles. These show a relatively flat slope in 1921 with a steepening in 1929, due to the ground water lowering that has occurred in the northern portion of the Edison-Arvin Unit.

In addition to the general plates just described, plates for each local ground water unit showing typical profiles of the ground water for 1921 and 1929, and continuous records of the fluctuations of representative wells for the period, 1921 to 1929, have been prepared. These are described with the discussion of each local unit.

Analyses of Ground Water Records.

Similar methods of presenting and analyzing the material relating to the use of ground water and the resulting effect on the ground water table have been used for nearly all local areas. To avoid repetition in the description of each unit, a general explanation applicable to all areas is here presented. The ground water records used in the analyses begin as early as 1917, for some of the areas, and are fairly complete for most of the upper San Joaquin Valley from 1921 to date. Many of these records have been secured by local organizations. A number of investigations also have been made by the state engineer in cooperation with local interests. The results of some of these studies have been published in other bulletins.* Additional investiga-

* Bulletin No. 9, "Water Resources of Kern River and Adjacent Streams and their Utilization," State Department of Engineering, 1920.
Bulletin No. 3, "Water Resources of Tulare County and their Utilization," State Department of Public Works, Division of Engineering and Irrigation, 1922.
Bulletin No. 11, "Ground Water Resources of the Southern San Joaquin Valley," State Department of Public Works, Division of Engineering and Irrigation, 1927.

tions have been made in connection with procedure relating to the various irrigation, water storage and water conservation districts. All of these data have been utilized in the preparation of this chapter.

Terms and Methods Used—In the analyses of canal and ground water records, presented in this chapter, certain terms and methods are used which it is advisable to define.

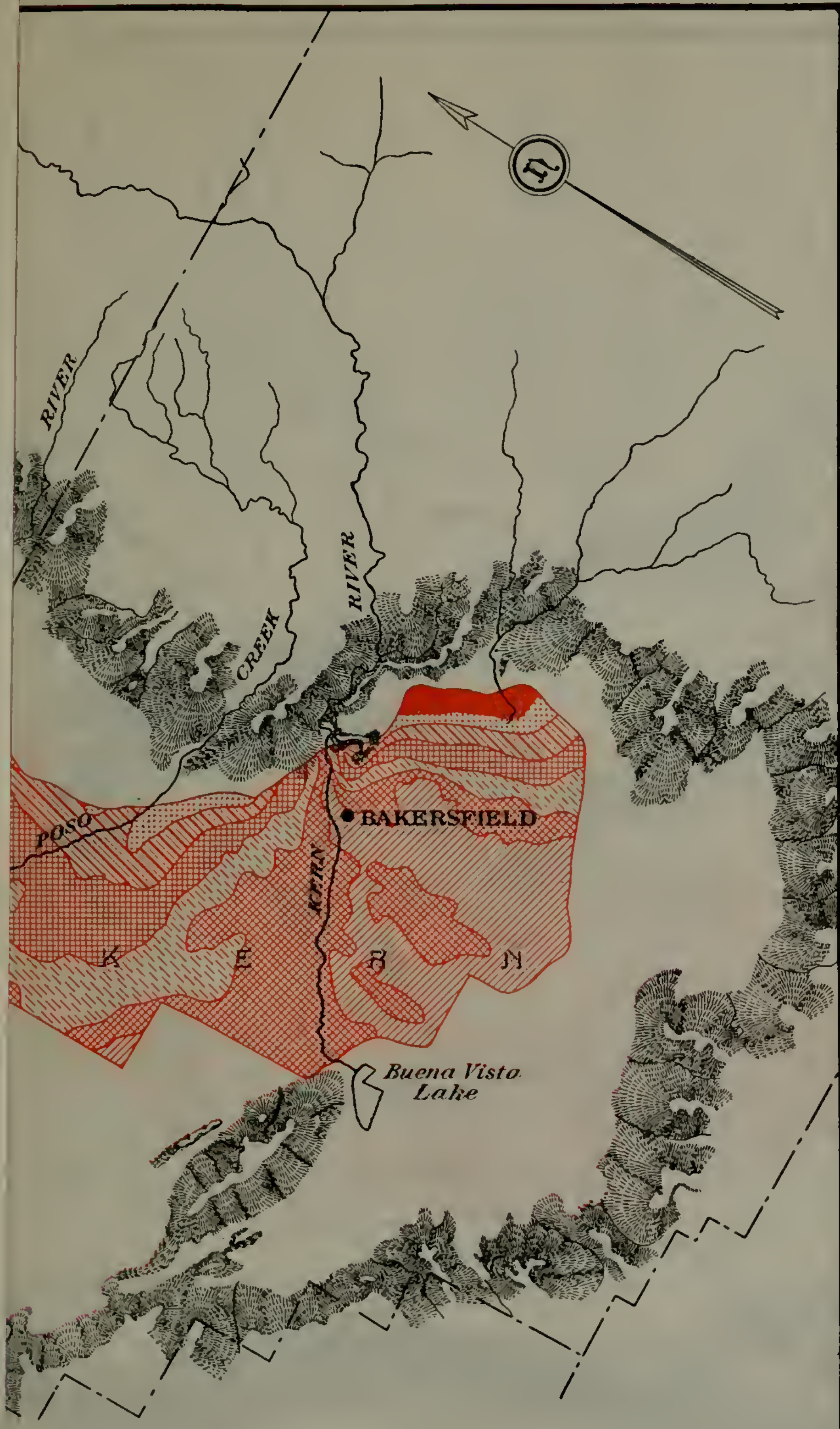
> "Consumptive Use" designates the amount of water actually consumed through evaporation and transpiration by plant growth.
> "Net Use" designates the sum of consumptive use from artificial supplies and irrecoverable losses.

For any particular ground water unit or basin, the portion of the net use termed irrecoverable losses comprises ground water outflow from the unit if any occurs, water consumed by natural vegetation in uncultivated or noncropped areas, and all other water lost or consumed other than that consumed directly in connection with the application of water for crop irrigation. An absorptive area receiving an average water suppy equal to its net use would maintain its ground water without progressive rise or fall. In a particular ground water unit, the rate of gross pumping may, and often does, exceed the rate of net use per unit area of irrigated crops. Such amounts of gross draft in excess of the net use percolate back to the ground water and become available for reuse by subsequent pumping. Net use, as the term has been defined, is limited to moisture received from sources other than direct rainfall on the area. The rainfall in the upper San Joaquin Valley, while helpful in meeting the moisture requirements of crops during the winter months, is insufficient to be a material ground water factor, by direct penetration of moisture to the water table or in meeting crop needs during the summer months, by retention in the surface soil. The precipitation in these areas serves to reduce the irrigation need during the winter months.

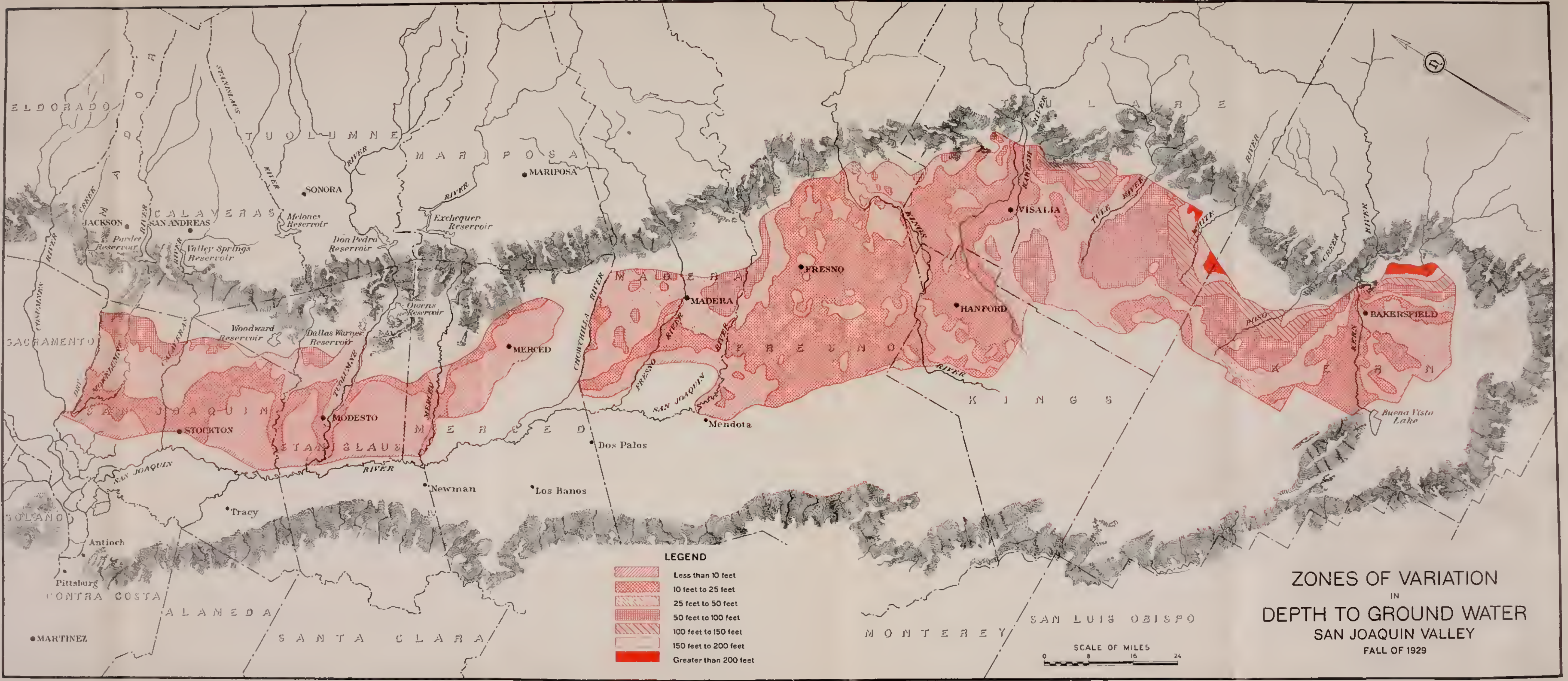
The volume of water represented by ground water fluctuations depends on the total extent of the fluctuations and the proportion of the soil volume filled or drained by the rise or lowering. While from 25 to 30 per cent of the total soil volume may represent the water drained from saturated coarse materials, the average per cent for the mixed materials, usually encountered in the alluvial fills of the San Joaquin Valley, is considerably less than 25 per cent. All moisture will not drain from any soil due to its capillary capacity.

"Drainage Factor" designates the per cent of the total soil volume represented by the water obtained by drainage. The percentage obtained by drainage for any material will be numerically the same as that required for its resaturation when a ground water rise occurs. While over 25 per cent may be drained from coarser materials, the materials within the zone of ground water fluctuation usually include some impervious materials so that the average drainage factor is generally less than that for the coarser materials alone.

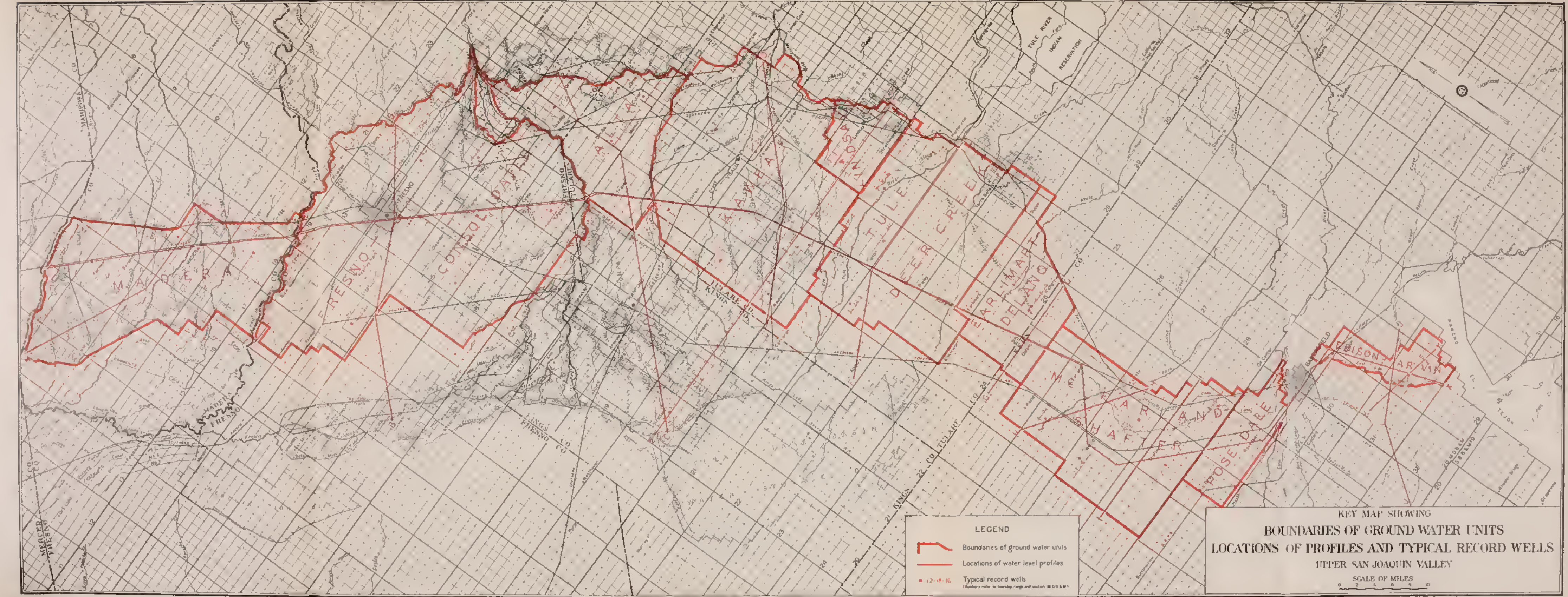
The records of areas irrigated, used in this chapter in studies of net use, were secured from the irrigation organizations where available, and by field canvass where not otherwise obtainable. In most sections, these data represent essentially the net service areas, and in fully



ZONES OF VARIATION
IN
DEPTH TO GROUND WATER
SAN JOAQUIN VALLEY
FALL OF 1929

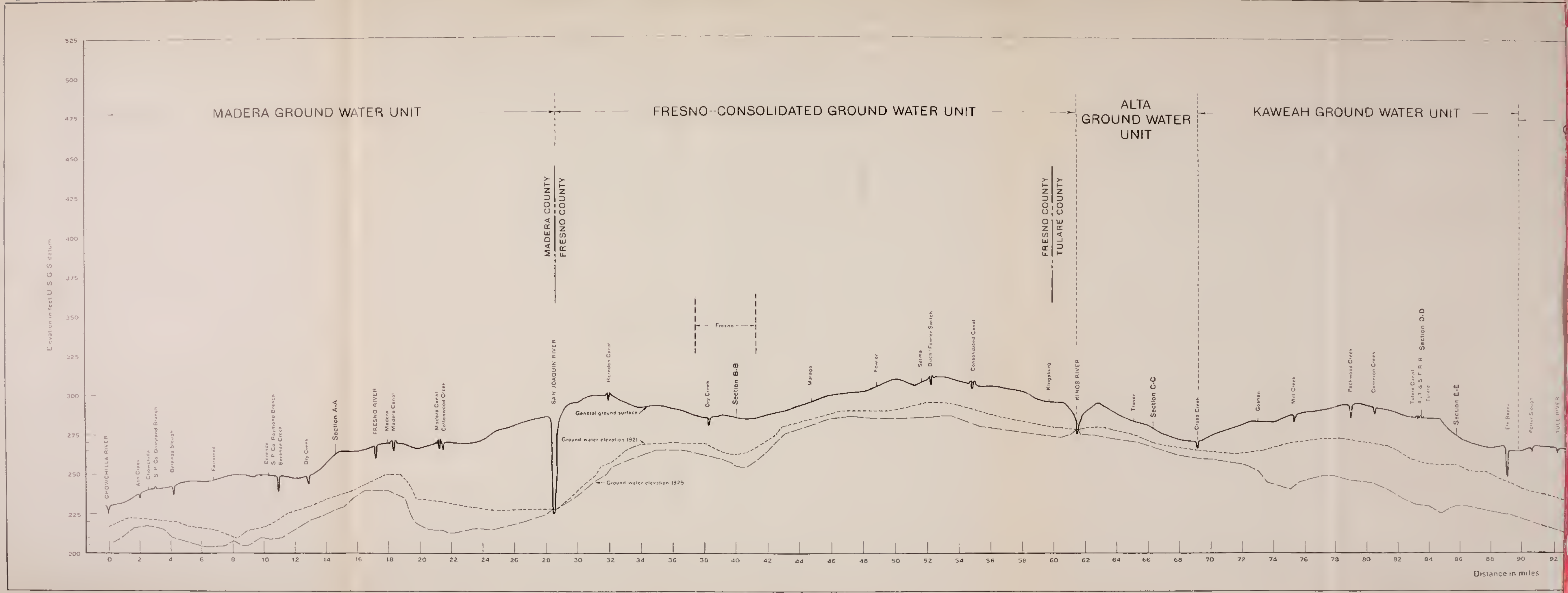

ZONES OF VARIATION
IN
DEPTH TO GROUND WATER
SAN JOAQUIN VALLEY
FALL OF 1929
LEGEND
Less than 10 feet
10 feet to 25 feet
25 feet to 50 feet
50 feet to 100 feet
100 feet to 150 feet
150 feet to 200 feet
Greater than 200 feet
SCALE OF MILES
0 8 16 24
ELDORADO
AMADOR
TUOLUMNE
MARIPOSA
CALAVERAS
SACRAMENTO
SAN JOAQUIN
STANISLAUS
MERCED
MADERA
FRESNO
KINGS
TULARE
KERN
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
MONTEREY
SAN LUIS OBISPO
JACKSON
SAN ANDREAS
SONORA
MARIPOSA
MERCED
MADERA
FRESNO
VISALIA
HANFORD
BAKERSFIELD
STOCKTON
MODESTO
Mendota
Dos Palos
Los Banos
Newman
Tracy
Antioch
Pittsburg
MARTINEZ
Pardee Reservoir
Valley Springs Reservoir
Melones Reservoir
Don Pedro Reservoir
Exchequer Reservoir
Owens Reservoir
Woodward Reservoir
Dallas Warner Reservoir
Buena Vista Lake
SAN JOAQUIN RIVER
KINGS RIVER
TULE RIVER
KAWEAH
WHITE
POSO
KERN
CHOWCHILLA RIVER
FRESNO RIVER
MERCED RIVER
TUOLUMNE
STANISLAUS RIVER
COSUMNES RIVER
MOKELUMNE
CALAVERAS
DRY CREEK

80997



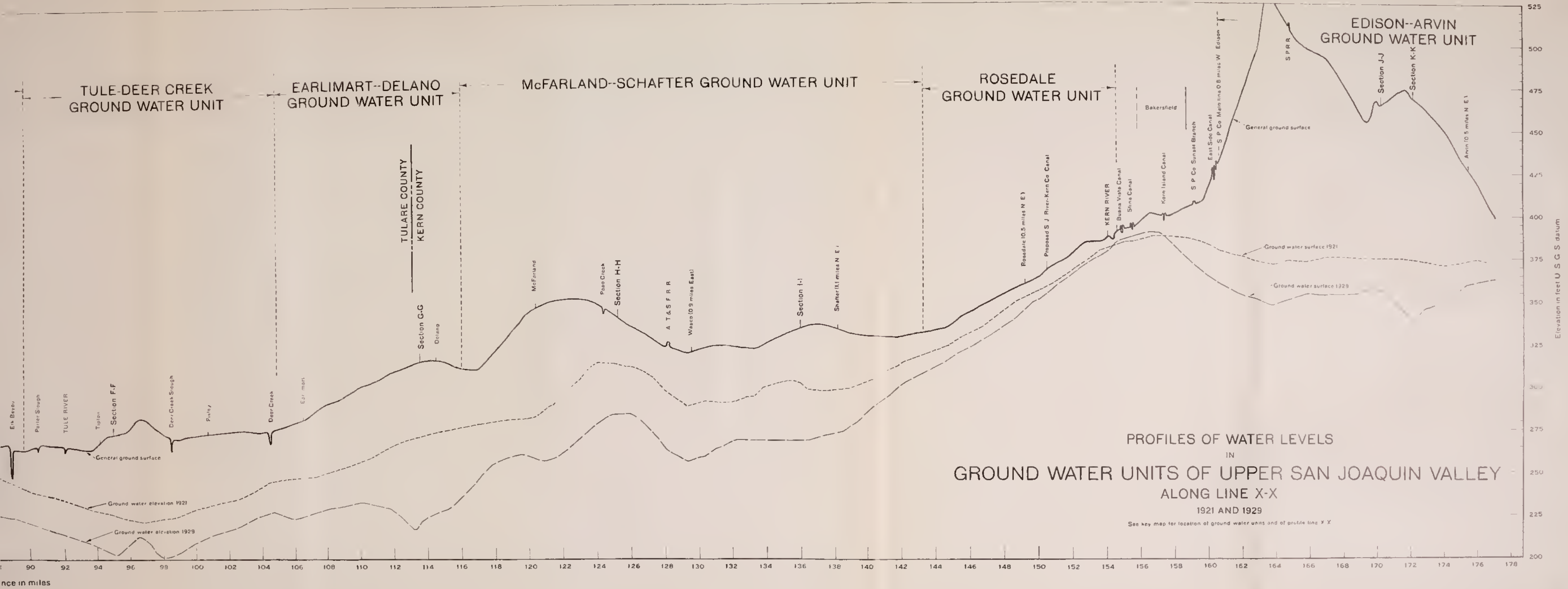
KEY MAP SHOWING
BOUNDARIES OF GROUND WATER UNITS
LOCATIONS OF PROFILES AND TYPICAL RECORD WELLS
UPPER SAN JOAQUIN VALLEY
SCALE OF MILES

80997



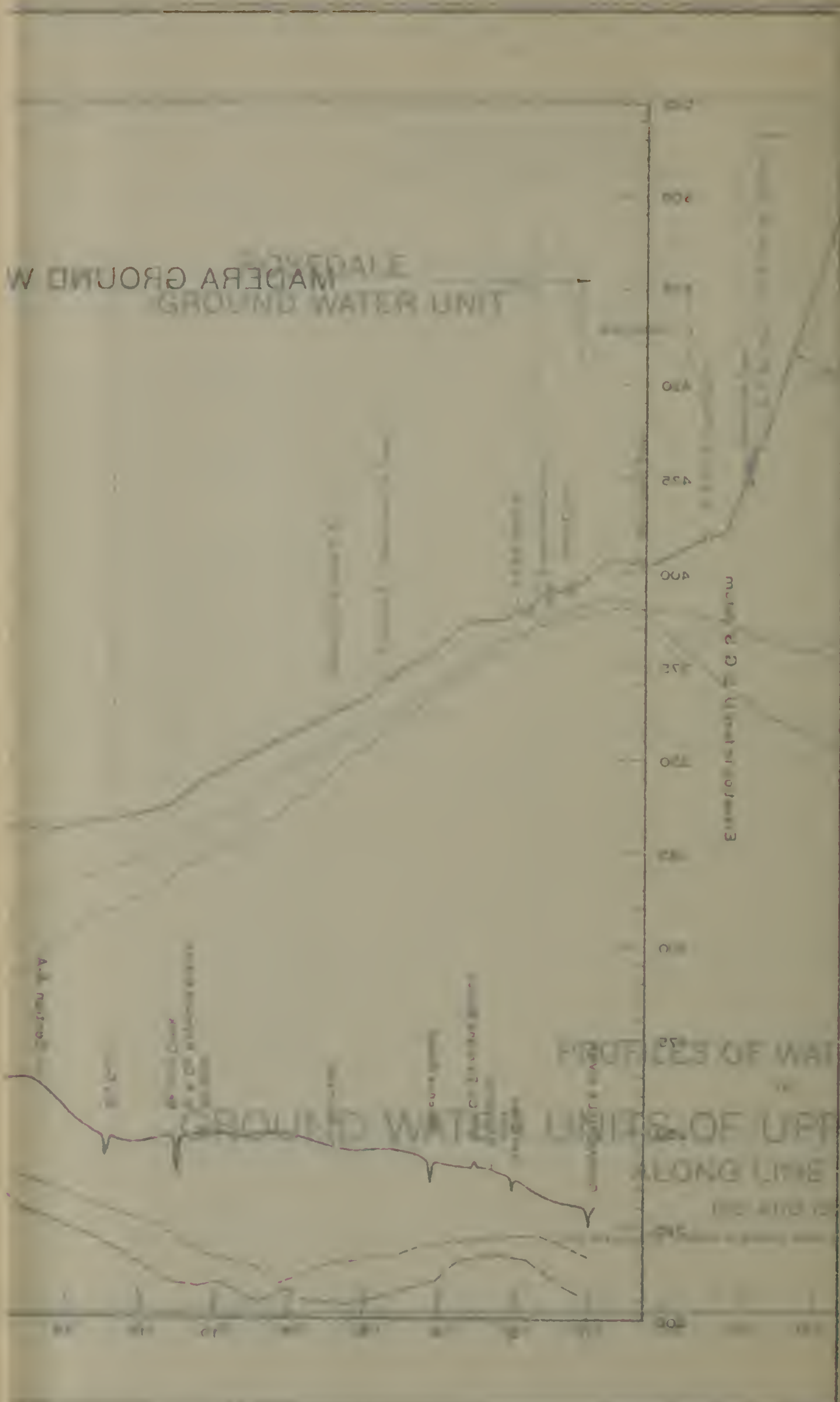
MADERA GROUND WATER UNIT
FRESNO-CONSOLIDATED GROUND WATER UNIT
ALTA GROUND WATER UNIT
KAWEAH GROUND WATER UNIT
MADERA COUNTY
FRESNO COUNTY
FRESNO COUNTY
TULARE COUNTY
Elevation in feet U S G S datum
525
500
475
450
425
400
375
350
325
300
275
250
225
200
CHOWCHILLA RIVER
Ash Creek
Chowchilla
S P Co Dairyland Branch
Berenda Slough
Fairmead
Berenda
S P Co Raymond Branch
Berenda Creek
Dry Creek
Section A-A
FRESNO RIVER
Madera
Madera Canal
Madera Canal
Cottonwood Creek
SAN JOAQUIN RIVER
Herndon Canal
Fresno
Dry Creek
Section B-B
Malaga
Fowler
Selma
Ditch (Fowler Switch
Consolidated Canal
Kingsburg
KINGS RIVER
Traver
Section C-C
Cross Creek
Goshen
Mill Creek
Packwood Creek
Cameron Creek
Tulare Canal
A, T & S F R R
Tulare
Section D-D
Section E-E
Elk Bayou
Porter Slough
TULE RIVER
General ground surface
Ground water elevation 1921
Ground water elevation 1929
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
92
Distance in miles

80997



PROFILES OF WATER LEVELS
IN
GROUND WATER UNITS OF UPPER SAN JOAQUIN VALLEY
ALONG LINE X-X
1921 AND 1929

See key map for location of ground water units and of profile line X X


GROUND WATER UNIT
PROFILES OF WAT
GROUND WATER UNITS OF UPP
ALONG LINE

developed sections would average about 80 per cent of the gross area of irrigable lands. Lands which are nonirrigable, due to roughness or other factors, have been excluded from the irrigable areas in the land classification.

Determination of the Water Supply Required to Meet Net Use Requirements—In areas where losses by seepage and percolation from canals and irrigated lands are recovered by pumping and re-used, it is necessary to bring to such areas sufficient water only to meet the net use. Several areas in the upper San Joaquin Valley are now developed on the basis of re-use of the percolation to the ground water. Consequently in plans for meeting the water requirements of such areas it is necessary to estimate the amount of net use. The best basis for such an estimate is the actual experience in the areas now under this type of development. If more water is delivered to any area than is consumed by transpiration, evaporation and irrecoverable losses, the excess will percolate to the ground water and cause it to rise. If less is delivered than the net use and the shortage in supply made up by pumping, a lowering of the water table will occur. The records of supply, areas irrigated and ground water fluctuations in many areas enable estimates to be made of the rate of supply required for the mean net use without progressive rise or fall of the water table. A graphical method of making such estimates was used for several areas in the upper San Joaquin Valley, in analyses presented in Bulletin No. 11, previously referred to. A similar method has been used in this report, generally applied, however, to larger units of area. The method consists in plotting the water supply for each season, in terms of acre-feet of measurable net inflow per acre irrigated, against the change in ground water elevation, expressed in feet for the same season. Such plotting for different years indicates the relationship between supply and changes in ground water level. A mean line expressing such relationship is drawn. The intersection of this line with the zero line of the scale of fluctuation indicates, on the scale for inflow, the acre-feet per irrigated acre needed to meet the net use, including the difference between unmeasurable inflow and outflow, without progressive ground water change. The supply used in such comparisons is the sum of all measurable sources of inflow less all similar measurable items of outflow. The product of the unit net use so determined and the average area irrigated during the period of record, shows the mean seasonal net supply which would have been necessary to meet the crop requirements and irrecoverable losses without progressive rise or fall of the ground water. The difference between the seasonal inflow, thus derived, and the mean actual inflow for the period indicates the average shortage of supply for areas where lowering has occurred. This method of analysis assumes that the requirements for net use are met in all years without shortage. This condition is generally met for lands served from wells, but is not always met in years of deficient canal supply for crops dependent on such canal service alone. The method includes, in the determination of net use, the net difference between the ground water inflow and outflow. Neither of these items are directly measurable. The net use determined by this method also includes water used by natural vegetation and uncultivated areas. These inclusions result in variations in net use per unit of area of irrigated crops in different ground water units.

The data available indicate that, in most parts of the upper San Joaquin Valley, general ground water movements from one area to another involving much distance are relatively slow and the quantities involved are generally small and have relatively little effect upon the net use within the areas. The method also is based on the assumption that, on the average, an equal amount of water is released per foot of lowering or that the average drainage factor is constant throughout the full depth of fluctuation. Within usual ranges of fluctuation this assumption is probably closely correct.

Ground water depletion estimates for the units, in which the ground water fluctuations vary consistently with the seasonal inflow, have been based upon the assumption that the average annual depletion is equal to the average annual shortage of net use requirements. An assumed drainage factor is not used in this method of analysis. The actual value of this factor is indicated by the ratio of the average annual depletion, in acre-feet, to the average annual volume of soil drained, expressed in acre-feet. For example, in Table 44, the gross area of the Fresno-Consolidated Ground Water Unit is given as 700 square miles or 448,000 acres. The average area irrigated for the 8-year period 1921–1929 is 319,900 acres and the average seasonal water supply diverted into the unit is 537,000 acre-feet. The average seasonal fall of ground water level is 0.81 foot. On Plate XX it is demonstrated graphically that a supply of 1.90 acre-feet per acre of cropped area would meet crop needs and maintain a constant ground water level. The average seasonal water requirement for this area equals 319,900 acres times 1.9 acre-feet per acre or 607,800 acre-feet. The average annual depletion equals 607,800 acre-feet minus 537,000 acre-feet or 70,800 acre-feet. The depletion per foot of lowering equals 70,800 acre-feet divided by 0.81 foot or 87,400 acre-feet. The soil volume drained per foot of lowering equals 448,000 acre-feet. Therefore, the drainage factor equals 87,400 acre-feet divided by 448,000 acre-feet or 19.5 per cent. While no method of ground water analysis can be exact, due to the many variable factors involved, the generally consistent variations of the annual fluctuations with the water supply, for the several areas, and number of years for which records are now available, indicate that the method is generally applicable to the conditions existing in these areas. The analyses of net use in the various ground water units have been made for the 8-year period 1921–1929, for which records of inflow, irrigated areas and ground water fluctuations are available.

Kern River Areas.

The Kern River areas as the term is here used cover the same area as Hydrographic Division No. 1 on Plate VI. It includes those portions of the upper San Joaquin Valley for which Kern River is the main source of water supply, although many parts of the area are not reached by the present systems diverting from Kern River. It includes all of the portions of Kern County in the San Joaquin Valley except the northern three miles.

The water of Kern River is divided between two groups of canal interests in accordance with the Miller-Haggin agreement. The flow of the river is measured at "First Point of Measurement" which is above all diversions in the valley. From March 1 to September 1, one-third of the flow at First Point in excess of 300 second-feet is delivered at "Second Point of Measurement," located on Kern River about five miles above its point of discharge into Buena Vista Slough, for use on lower lands. The remainder of the flow is diverted by the different canals between First Point and Second Point, to the extent of their capacities. These canals have varying priorities which result in differences in the character of service received by different parts of the canal served areas. At present there is no storage on Kern River above Second Point. Buena Vista Lake acts as a reservoir for part of the "Second Point" water.

Investigations relative to the utilization of the water supply of Kern River were made, during 1920, by the State Engineer in cooperation with Kern County and local interests. In 1923 the Kern River Water Storage District, comprising about 250,000 acres, was formed. Its area corresponded generally with that recommended in the report of the 1920 investigations for service above "Second Point." Extensive investigations were conducted by the storage district and a plan prepared which included the utilization of ground water storage and pumping for areas on the south side of the river in order that water now diverted from the river for use in this area, in excess of net use, might be used for higher lands on the north side of the river. Although such a plan would have resulted in a much more complete and economical use of the available water supply, the various local interests involved were unable to agree regarding its accomplishment and the district was dissolved in 1929.

Most of the important canals using "First Point" water operate as public utilities. These utilities recognize certain lands as having rights to service under the different canals. A number of questions regarding the definition of service, areas and rates have been involved in proceedings before the California Railroad Commission. The areas irrigated in each year vary with the run-off. An area of about 165,000 acres is served usually, under all ditches, with additional areas in years of above normal supply. The records of the canal companies show an average annual diversion of 413.000 acre-feet for the period 1893 to 1925, inclusive. The adequacy and distribution of the supply through the season vary with the different canals, those of early priority having a generally well distributed service.

For purposes of discussion, the area as a whole has been divided into smaller local areas and ground water units having similar conditions. These divisions, in the order presented, consist of the Edison-Arvin Unit, canal served areas south of Kern River, Rosedale Unit, Pioneer Canal area, Buttonwillow and Semitropic Ridges, Buena Vista Water Storage District and McFarland Shafter Unit. In making the crop survey of 1929 for all units in Kern County, from which the area irrigated in each unit has been determined, all highways, railroads, county and private roads, incorporated and unincorporated towns, main canals, main laterals, sublaterals, and building and uncropped areas of more than one acre were excluded. Private ditches and building areas and yards of less than one acre, situated within the cropped areas, were included.

Edison-Arvin Unit—This unit includes the pump irrigated areas lying above the East Side Canal on the south side of Kern River. Its northern limit is that of the developed area between Bakersfield and Edison, from which it extends southward, a distance of fourteen miles, to the south line of Township 31 South. The eastern limit is that of the intensive development around Arvin and on the cone of Caliente Creek. A small intensive citrus development is located near Edison and an area devoted to both citrus and deciduous fruits extends from Edison westward past Magunden toward Bakersfield on both sides of the Southern Pacific Railroad. Although the principal source of replenishment for the ground water of this unit is the run-off of Caliente Creek, the cone of depression, that has developed during the past five years under this area of heavy pumping draft, has lowered the water table to elevations below that under the East Side Canal three miles to the west. The total irrigation development under pumping service for the portion of this area on the Caliente Creek fan is 17,400 acres. The gross area of the unit is 51 square miles and the area irrigated in 1929 was 31 square miles, or 20,000 acres.

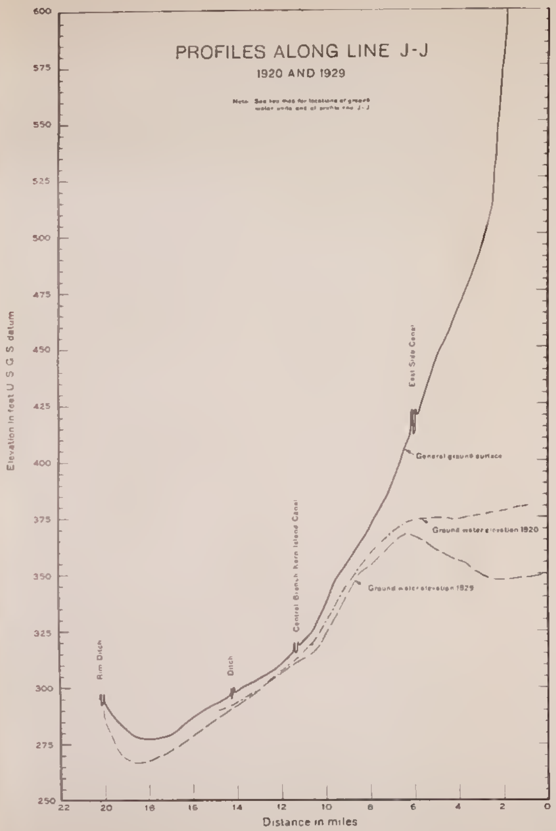
Profile J-J on Plate XIV, "Edison-Arvin Ground Water Unit," extends in a northeasterly direction from a point on the Rim Ditch, ten miles east of Buena Vista Lake, to a point about five miles southeast of Edison. It shows the slope condition in the canal served area south of Kern River as well as that in the Edison-Arvin Unit. Profile K-K, shown on same plate, extends about ten miles, in an easterly direction parallel to the Southern Pacific Railroad, from a point about eight miles south of Bakersfield. Both of these profiles, for the 1929 ground water elevations, show ground water depressions through the East Side Canal and the higher part of the Caliente cone. This has been caused by the excess of draft over supply for the period, 1921 to 1929, as the ground water slope was formerly continuous from the east toward the west. For Well 31–29–16, about eight miles south of Edison near the East Side Canal, the pumping draft and winter recovery are large for each season and amount to more than 30 feet in some years. There has, however, been a general lowering from 1924 to 1929. The characteristics of Well 31–29–23, about ten miles south of Edison and two miles east of the East Side Canal, are somewhat similar to those for Well 31–29–16. Well 29–28–36a, located about three miles westerly from Edison and near the East Side Canal, shows smaller lowering than the other two wells referred to, but is somewhat similar in its general characteristics with regard to winter recovery and general lowering.

The available records of water supply, area irrigated and ground water fluctuation are shown in Table 30. The ground water fluctuations shown in Table 30 do not vary consistently with the estimated run-off for the different years. Caliente Creek does not have a surface run-off in its stream channel that is accessible for measurement, as the flow is largely absorbed and moves slowly to the lower areas. The inconsistencies between the estimated annual run-offs and the resulting ground water fluctuations are due probably to some increasing influence of East Side Canal seepages and the time lag between surface run-off and delivery to the ground water in the area, and prevent the determination of a definite relationship between inflow and changes in

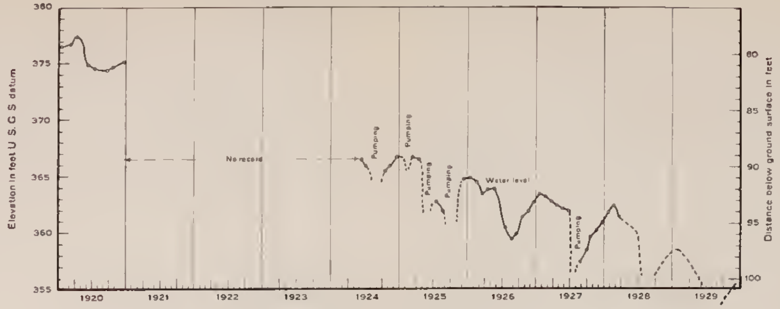
Edison-Arvin Unit—This unit includes the pump irrigated areas lying above the East Side Canal on the south side of Kern River. Its northern limit is that of the developed area between Bakersfield and Edison, from which it extends southward, a distance of fourteen miles, to the south line of Township 31 South. The eastern limit is that of the intensive development around Arvin and on the cone of Caliente Creek. A small intensive citrus development is located near Edison and an area devoted to both citrus and deciduous fruits extends from Edison westward past Magunden toward Bakersfield on both sides of the Southern Pacific Railroad. Although the principal source of replenishment for the ground water of this unit is the run-off of Caliente Creek, the cone of depression, that has developed during the past five years under this area of heavy pumping draft, has lowered the water table to elevations below that under the East Side Canal three miles to the west. The total irrigation development under pumping service for the portion of this area on the Caliente Creek fan is 17,400 acres. The gross area of the unit is 51 square miles and the area irrigated in 1929 was 31 square miles, or 20,000 acres.

Profile J-J on Plate XIV, "Edison-Arvin Ground Water Unit," extends in a northeasterly direction from a point on the Rim Ditch, ten miles east of Buena Vista Lake, to a point about five miles southeast of Edison. It shows the slope condition in the canal served area south of Kern River as well as that in the Edison-Arvin Unit. Profile K-K, shown on same plate, extends about ten miles, in an easterly direction parallel to the Southern Pacific Railroad, from a point about eight miles south of Bakersfield. Both of these profiles, for the 1929 ground water elevations, show ground water depressions through the East Side Canal and the higher part of the Caliente cone. This has been caused by the excess of draft over supply for the period, 1921 to 1929, as the ground water slope was formerly continuous from the east toward the west. For Well 31–29–16, about eight miles south of Edison near the East Side Canal, the pumping draft and winter recovery are large for each season and amount to more than 30 feet in some years. There has, however, been a general lowering from 1924 to 1929. The characteristics of Well 31–29–23, about ten miles south of Edison and two miles east of the East Side Canal, are somewhat similar to those for Well 31–29–16. Well 29–28–36a, located about three miles westerly from Edison and near the East Side Canal, shows smaller lowering than the other two wells referred to, but is somewhat similar in its general characteristics with regard to winter recovery and general lowering.

The available records of water supply, area irrigated and ground water fluctuation are shown in Table 30. The ground water fluctuations shown in Table 30 do not vary consistently with the estimated run-off for the different years. Caliente Creek does not have a surface run-off in its stream channel that is accessible for measurement, as the flow is largely absorbed and moves slowly to the lower areas. The inconsistencies between the estimated annual run-offs and the resulting ground water fluctuations are due probably to some increasing influence of East Side Canal seepages and the time lag between surface run-off and delivery to the ground water in the area, and prevent the determination of a definite relationship between inflow and changes in

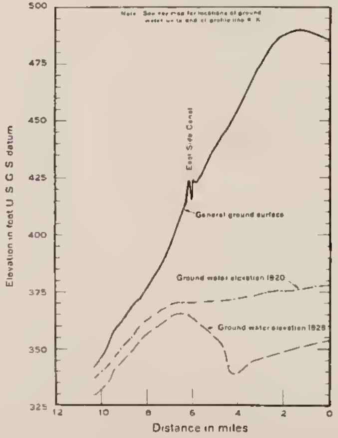


WATER LEVELS IN WELL 29-28-36a

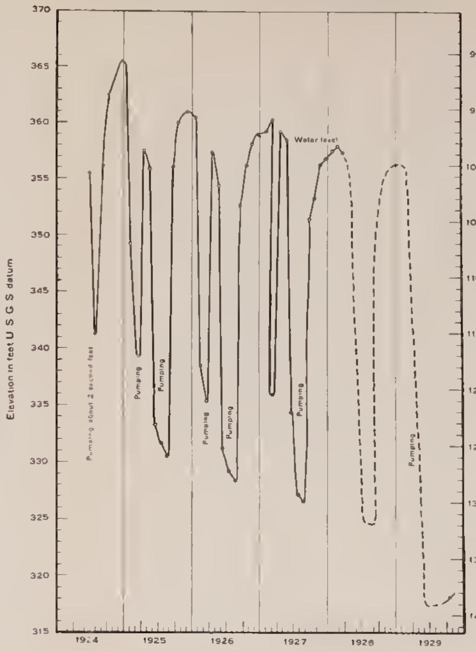


PROFILES ALONG LINE K-K

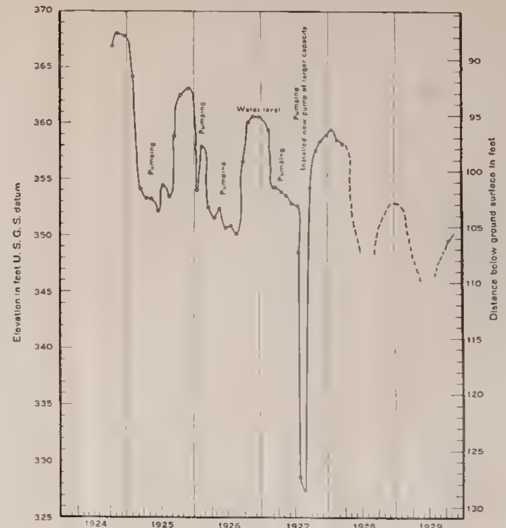
1920 AND 1929



WATER LEVELS IN WELL 31-29-16



WATER LEVELS IN WELL 31-29-23



EDISON-ARVIN GROUND WATER UNIT

TABLE 30

EDISON-ARVIN UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area 51 square miles

Season or period	Water supply. Run-off of Caliente Creek, in acre-feet	Area irrigated, in acres	Change of ground water level, in feet[3]
1921-24	77,800	(1)	[2]—9.57
1924-25	35,200	17,437	—0.89
1925-26	12,600	(1)	—2.34
1926-27	32,700	(1)	—3.44
1927-28	15,100	(1)	—1.28
1928-29	15,100	20,000	—3.99
Averages, 1921-29	23,600	18,600	—2.69

[1] Data not available.
[2] Interpolated for period 1921-1924, from 1920 and 1924 records.
[3] (—) indicates lowering of ground water level.

ground water level. The estimated run-off of Caliente Creek is also subject to considerable error as it is based on comparison with adjacent streams due to the lack of stream flow measurements. An average annual depletion of about 13,000 acre-feet has been estimated by subtracting the mean annual run-off of Caliente Creek from an estimated net use of two acre-feet per acre. This would indicate an average drainage factor of 15 per cent for this unit.

Canal-served Areas South of Kern River—The larger part of the "First Point" water is diverted to the area south of Kern River. This area is served by several different canals which are mainly under the control of the Kern County Canal and Water Company. The quantity of water available varies with the different canals and with the character of run-off of the individual seasons. The canal served area south of Kern River is compact, as a whole, except for the area served by the East Side Canal. The ground water is within six feet of the ground surface for about two-thirds of the total area of 90,000 acres, exclusive of the East Side Canal area. This area is one of the few remaining areas in the San Joaquin Valley having injuriously high ground water where no steps to remedy the condition have been taken. For much of this land, drainage is a greater need than additional water. There is comparatively little ground water development in this area although the recent dry years have caused the development of a number of wells for supplemental use. The adequacy of the canal supply has resulted in limited local interest in pumping. Wells of good yield are obtainable in the portions of the area near Kern River where coarser materials are encountered. Toward the south, from Kern Lake to Buena Vista Lake, artesian wells are obtainable. The water-bearing sands are fine, and wells of the gravel envelope type are most effective in securing large yields. The largest present draft on the ground water is that for municipal supply for the city of Bakersfield. The total present ground water draft is a very small proportion of the canal diversions into the area. A large portion of the area shows no lowering of ground water, and the maximum in any part is about five feet.

The area under the East Side Canal is separated from the main South Side Canal area by an intervening strip of alkali land in the topographic trough of the former course of Kern River. About 6000 acres of the gross area of 15,000 acres under the East Side Canal receive canal service. The average total annual diversions into the canal are about 25,000 acre-feet. About 60 per cent of the canal served area also secures a supplemental supply by pumping and an additional area of about 6000 acres is irrigated entirely from wells. Deeper wells within this area are seldom perforated in the upper strata, and are not immediately influenced by the flow of water in the canal or its use on overlying lands. Such supply as may be available in the deeper wells is considered to be received from the general ground water movement from higher areas tributary to Caliente Creek. These waters may now be intercepted, at least partly, by pumping in the areas nearer to Caliente Creek. From 1921 to 1929, the ground water in this area has lowered generally from ten to twenty feet at the north end to five to fifteen feet at the south end. Present depths to water vary from twenty-five to sixty feet.

Rosedale Unit—The Rosedale unit lies immediately south of the Seventh Standard Parallel and extends southward for a distance of five and one-half miles. Its eastern limit is along the Kern River near Bakersfield, and the western boundary is near Rio Bravo. It is served by the Calloway, Beardsley, McCaffrey and Emery canals. The areas irrigated from these canals vary with the run-off of the different years. Table 31 sets forth the available data on water supply, areas irrigated and ground water changes in this unit.

TABLE 31

ROSEDALE UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area 79 square miles

Season	Water supply to unit, in acre-feet	Area irrigated, in acres			Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
		By canal service	By pumping	Total		
1919–1920	77,850	15,250	2,600	17,850	4.36	------------
1920–1921	56,500	11,600	3,200	14,800	3.82	—0.98
1921–1922	98,750	15,550	2,600	18,150	5.44	+1.08
1922–1923	68,800	12,650	3,000	15,650	4.40	—1.04
1923–1924	0	0	6,000	6,000	0	—3.45
1924–1925	35,850	7,800	4,000	11,800	3.04	—2.01
1925–1926	28,400	6,100	4,000	10,100	2.81	—1.35
1926–1927	104,500	13,450	4,000	17,450	5.99	+1.37
1927–1928	25,000	6,000	4,000	10,000	2.50	—1.23
1928–1929	12,100	2,900	4,000	6,900	1.75	—3.64
Averages, 1921–1929	46,700	8,050	3,950	12,000	3.89	—1.28

[1] (+) indicates a rise and (—) a fall in ground water level.

The relationship between the supply per acre of irrigated area and the resulting ground water fluctuation is fairly consistent. However, the indicated rate of gross delivery required to maintain the ground water is about 4.6 acre-feet per acre. This figure is far in excess of consumptive use and is probably the result of the ground water outflow through the coarse materials in this area, due to its proximity to the channel of Kern River. Some of this outflow is used in other areas. Based upon the difference between the actual inflow and an average requirement of 4.6 acre-feet per acre, the indicated mean annual depletion of ground water for the period 1921–1929 is approximately 9000 acre-feet, and indicates a drainage factor of about 14 per cent. Prior to canal irrigation, the ground water was about 50 feet lower than at present. The additions to the ground water from irrigation have changed the ground water slopes so that outward movement now occurs. In the earlier years shown in Table 31 the ground water was sufficiently high to result in loss by soil moisture evaporation from larger areas than the cropped areas given. If a rate of net use, similar to that indicated for other areas, is applied to this area for each year, the resulting unaccounted for water varies widely in different years. During the period 1921–1929 the average seasonal supply exceeded the probable use within the area by about 20,000 acre-feet. In years of larger supply the unaccounted for water is a larger amount. The outflow from this area appears to be responsive to the extent of the supply in each year. The total lowering, from 1921 to 1929, amounting to 10.27 feet, appears to have reduced but not to have eliminated ground water outflow losses in this area.

Pioneer Canal Area—This area covers the lower area north of Kern River, served mainly by the Pioneer Canal. The area irrigated varies with the extent of stream flow in different years and may exceed 12,000 acres in years of large run-off. The canal diversions average about 27,000 acre-feet per year. There is only a limited amount of present use of ground water in this area, although the ground water supply and conditions for pumping are generally favorable. The records of ground water fluctuations are not complete. Those available indicate that some outflow of ground water occurs and that there is probably some ground water inflow from the Rosedale area. Only limited lowering has occurred since 1920.

Buttonwillow and Semitropic Ridges—This area covers the lands along Goose Lake Slough and the adjacent Buttonwillow and Semitropic ridges. There is some irrigation along Goose Lake Slough from wells, largely artesian. As discussed in Chapter III, these lands are generally of poor quality and there is little irrigation development. Toward the northern end a number of wells supply water for duck club use. The records of ground water fluctuations in this area are incomplete. Some wells which formerly flowed now require pumping. Wells pumped during the summer may recover their pressure head and resume flow during the winter season of smaller draft. While there are no surface sources of inflow into this area, ground water movement may occur from adjacent areas at the east and south.

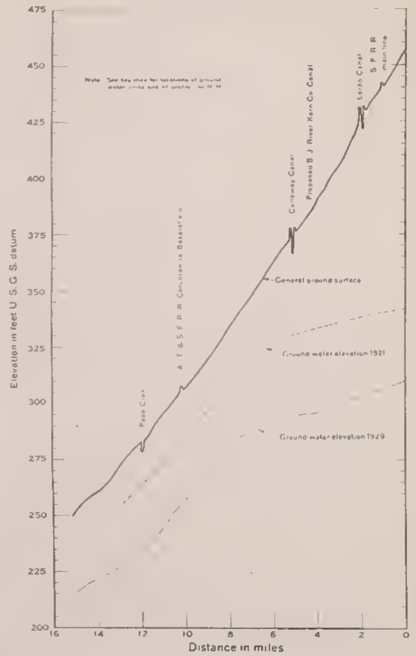
Buena Vista Water Storage District—The "Second Point" water on Kern River is now handled by the Buena Vista Water Storage District. This district contains 78,825 acres including the area of Buena Vista Lake and the valley trough lands extending north to Wasco Road. When organized, about 90 per cent of the land was owned by Miller and Lux, Inc. A portion of the district has since been colonized. Formerly the area irrigated varied with the available run-off, Buena Vista Lake being used for storage. This lake is one of the natural depressions in which excess stream flow collected. The area of submergence is now limited by levees. The depth of flooding is shallow and evaporation losses represent a large part of the water stored. Ground water is fairly close to the surface in much of the area irrigated. The water-bearing materials consist of fine sand which require wells adapted to such conditions, if good yields are to be secured. There has been considerable recent pumping development in the southern part of the main area of the district which has made available a more complete and dependable water supply.

McFarland-Shafter Unit—This unit extends southward from a line three miles south of the Tulare County line, a distance of 21 miles, to the Seventh Standard Parallel. The eastern boundary is about two miles east of the Southern Pacific Railroad and the State highway, and the western limit is the west line of Range 24 East. Part of the eastern portion receives canal service from the Lerdo and Calloway canals. As these canals have flood water rights only, the water supply available varies widely in different years. Poso Creek also supplies some stream flow to the northern part of the area. The gross area is 310 square miles. Table 32 summarizes the available data on water supply, irrigated area and ground water fluctuation for the period 1919–1929, inclusive. The average lowering for the full area has been three feet per year. The lowering has varied in the different parts of the area as shown on Plate X. A total lowering of as much as 40 to 45 feet has occurred in some of the more heavily pumped areas. In the southwest part of the area near Goose Lake Slough, where the ground water draft is slight, little lowering has occurred. The lowering is generally less in the poorer lands along the west side and beyond the areas now developed.

The average ground water fluctuation is plotted against the average water supply per acre for each of the nine years of record on Plate XV, "McFarland-Shafter Ground Water Unit." The points for the different years are scattered somewhat but indicate generally that an inflow of two acre-feet per acre will meet the crop requirements and maintain the ground water at its present level with such unmeasurable ground water outflow or inflow as may now occur. Part of the variations in individual years are due probably to the difference in use on canal-served areas which may receive only partial service. Some ground water outflow to the west also may occur. Such outflow probably would be somewhat larger under the higher ground water conditions of 1922 than at present. Prior to irrigation in this area, the ground water was about 50 feet lower than in 1920. About one-half of the subsequent rise had been lost by 1929. The ground water level, prior to irrigation, was that maintained by the balance of natural inflow and outflow. The natural inflow is represented by the absorption from Poso Creek. The actual pump draft in this area was found by canvass of all plants in 1920 to exceed two acre-feet per acre. Pumped water in excess of net use will return to the ground water as deep percolation and is only a temporary draft on the supply. With full recovery of ground water, a delivered supply into this area of two acre-feet per acre of cropped area should meet the crop requirements and such outflow as may occur, with present ground water elevations, and prevent further ground water lowering. The 1921–1929 average annual ground water depletion is assumed to equal the difference

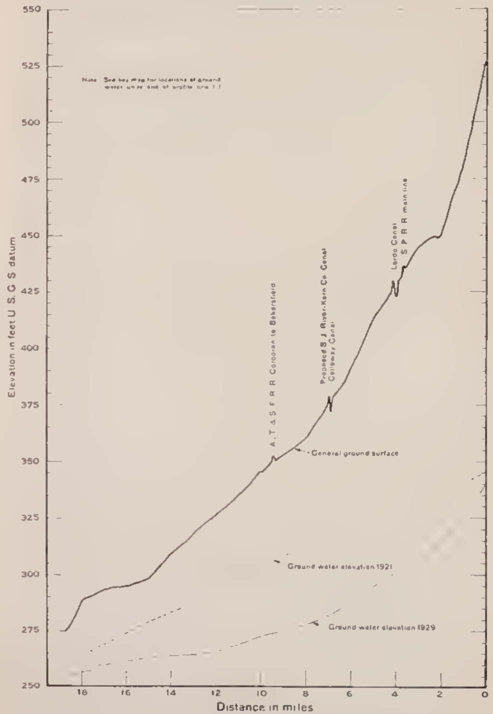
PROFILES ALONG LINE H-H

1921 AND 1929

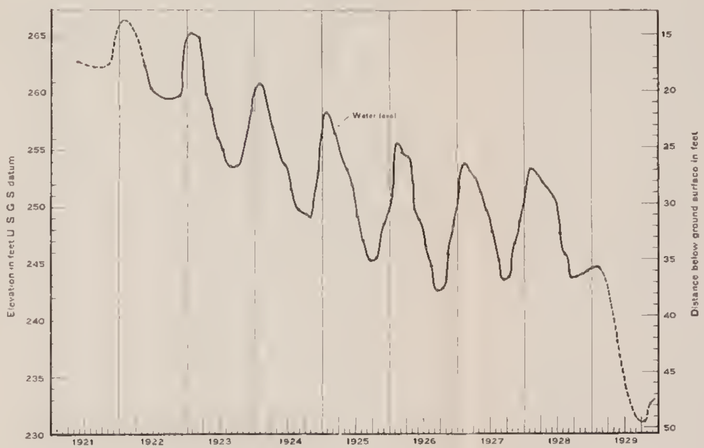


PROFILES ALONG LINE I-I

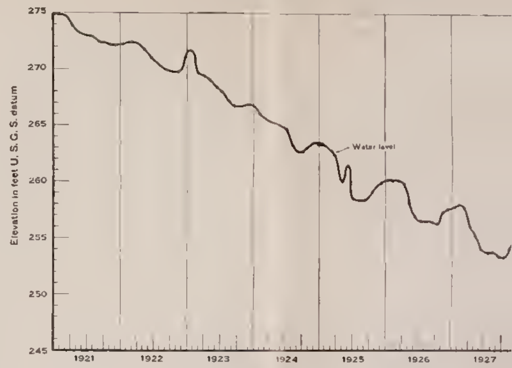
1921 AND 1929



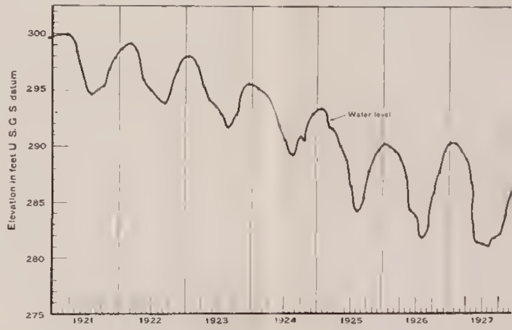
WATER LEVELS IN WELL 26-24-11



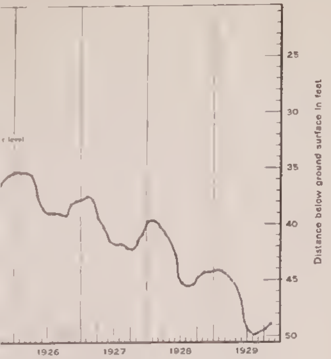
WATER LEVELS IN WELL 27-24-10



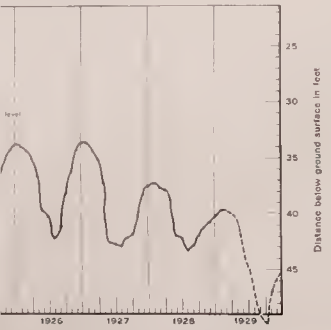
WATER LEVELS IN WELL 28-25-21



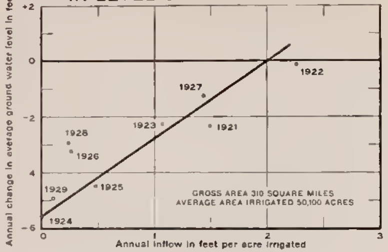
WELL 27-24-10



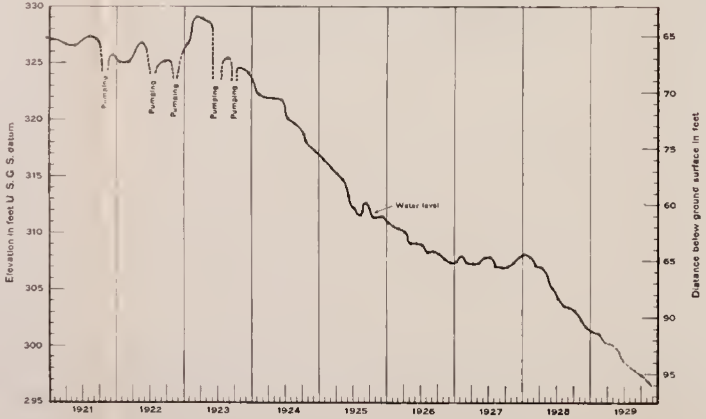
WELL 28-25-21



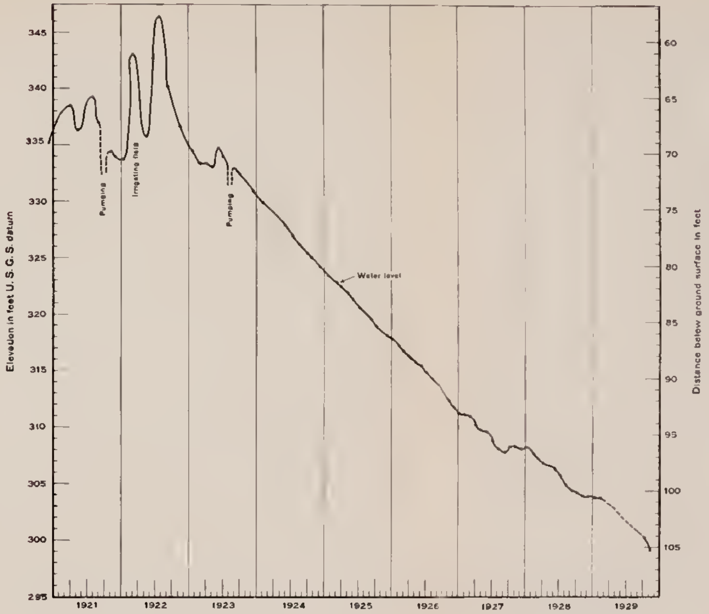
RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER



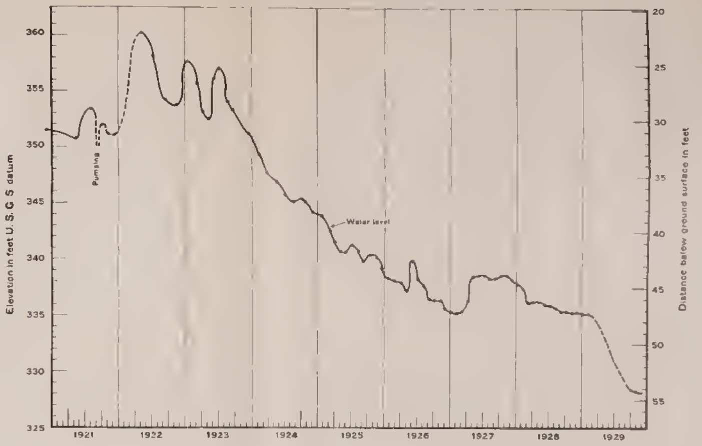
WATER LEVELS IN WELL 27-25-26



WATER LEVELS IN WELL 27-25-1



WATER LEVELS IN WELL 28-26-26a



McFARLAND-SHAFTER GROUND WATER UNIT

TABLE 32

McFARLAND-SHAFTER UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area—310 square miles

Season	Water supply to unit, in acre-feet				Area irrigated, in acres			Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[3]
	Lerdo Canal	Calloway Canal	Poso Creek[1]	Total net inflow	By pumping from ground water[2]	From canals	Total		
1919-1920	8,050	48,100	7,250	63,400	30,800	14,100	44,900	1.41	
1920-1921	11,100	43,900	2,500	57,500	34,100	4,300	38,400	1.50	—2.35
1921-1922	19,600	97,700	5,800	123,100	37,200	17,200	54,400	2.26	—0.18
1922-1923	12,600	31,800	8,050	52,450	39,700	9,800	49,500	1.06	—2.26
1923-1924	0	0	0	0	42,000	0	42,000	0.0	—5.58
1924-1925	4,100	13,700	5,600	23,400	43,800	4,600	48,400	.48	—4.49
1925-1926	4,400	6,200	3,000	13,600	45,400	5,500	50,900	.27	—3.23
1926-1927	12,750	63,300	6,000	82,050	46,800	9,400	56,200	1.46	—1.21
1927-1928	4,600	4,200	3,000	11,800	48,000	1,600	49,600	.24	—2.98
1928-1929	1,750	1,050	2,000	4,800	49,160	640	49,800	.10	—4.91
Averages, 1921-1929	7,480	27,240	4,180	38,900	44,010	6,090	50,100	.77	—3.10

[1] Measured run-off reduced by 2,000 acre-feet for estimated use above this area.
[2] Irrigated area records for 1921, 1924 and 1929; other years interpolated.
[3] (—) indicates lowering of ground water level.

between the required seasonal net use of approximately 100,000 acre-feet for the area under irrigation, and the estimated mean seasonal inflow of about 39,000 acre-feet, or 61,000 acre-feet. This would indicate an average drainage factor of about 10 per cent for this unit.

Profile H-H on Plate XV extends generally parallel to Poso Creek from Famoso to beyond Elmo. The areas under the Lerdo and Calloway canals receive irregular canal service. Pumping is practiced near the lower end of the area crossed by the profile. There has been very little canal service in this area in recent years and larger lowering has occurred in the canal areas than in the pumping areas.

Profile I-I extends east and west near Shafter. Little lowering has occurred at the upper end above the canals. A lowering of about 30 feet is shown in the pumping area near Shafter. At the west, where there is little development, only limited lowering occurred.

Well No. 26–24–11, Plate XV, is located west of Elmo in the edge of the pumping area. Lowering occurs during the summer pumping season with a winter recovery. The winter peaks show an average annual lowering of about two feet each below the peak of the previous year until 1929, except for the winters following the larger supplies of 1922 and 1927, which caused relatively greater winter recoveries. Winter recovery was very small in the winter of 1928–29 and larger lowering occurred in the summer of 1929.

Well No. 27–24–10 is west of the pumping area near Wasco. It shows a continuous lowering of about three feet per year with a small winter recovery from the summer draft.

Well No. 27–25–26 is east of Shafter under the Lerdo Canal. It maintained its level with some gain to 1923 and has dropped steadily since, with the exception of holding even in 1927. Lowering has averaged between four and five feet per year since 1923. The years of lowering are ones of small flow in the Lerdo Canal.

Well No. 27–25–1 is at the side of Poso Creek near Famoso. It shows a marked response of about ten feet to adjacent irrigations in 1922, dropping back quickly after the irrigation. Since 1923 it has lowered steadily at an average rate of about five feet per year. The larger supply in 1927 only reduced the rate of lowering in that year to three feet.

Well No. 28–26–26a is near the Calloway Canal at the southern side of this area. It shows response to adjacent canal use, holding its level in 1922 and 1923, lowering through 1926, gaining enough in 1927 to balance the lowering in 1928, and lowering seven feet in 1929.

Wells in the eastern part of this area do not show a winter recovery. The winter recovery at the west is probably, or at least partly, a pressure recovery similar to the pressure recovery that causes some wells farther west to resume flow during the winter. The winter recovery indicates that some movement occurs, the lowering in the upper areas being reflected by the rise in the lower areas.

Earlimart-Delano Unit.

This unit includes the pump developed areas around those two towns. It is bounded on the north by the division between the areas affected by White River and Deer Creek, and extends southward for eleven miles to an east and west line three miles south of the north line of Kern County. The eastern limit is along the Southern Pacific branch line between Richgrove and Ducor and the western limit is the west line of Range 25 East. This area has only very limited tributary run-off. White River is the only stream draining higher foothill areas. There are additional minor lower drainage areas such as Rag Gulch. All irrigated areas are served entirely by pumping from wells. The generally high quality of the lands in this area has resulted in a relatively large area of pumping. The available records on water supply, areas irrigated and ground water fluctuation are assembled in Table 33. The areas irrigated are based on direct canvass in 1921, 1924, 1925 and 1929 with interpolations for intervening years. A continual increase is shown with a total increase of about 160 per cent in nine years.

In making the crop survey of 1929 for all units in Tulare County, from which the areas irrigated in each unit has been determined, all highways, railroads, incorporated and unincorporated towns, main canals, main laterals, sublaterals and building and uncropped areas of more than one acre were excluded. County and private roads, private ditches and building areas and yards of less than one acre situated within the cropped area were included.

Table 33 shows the average ground water fluctuation in the Earlimart-Delano Unit for each year. Plate X shows the total lowering for the eight-year period, from 1921 to 1929. The lowering has been largest eastward from Delano in the area of heaviest development. A maximum lowering of 70 feet with lowering in excess of 50 feet over a relatively large area is shown. The ground water contours on Plate VIII show that the lowering has resulted in a ground water depression in the area of heaviest pumping, with the ground water sloping into this area from all sides.

TABLE 33

EARLIMART-DELANO UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 150 square miles

Season	Water supply. Estimated run-off of White River, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1920-1921	2,200	11,600	0.19	
1921-1922	3,700	13,000	0.29	—1.93
1922-1923	4,800	14,500	0.33	—3.24
1923-1924	0	15,950	0.0	—3.77
1924-1925	3,600	20,000	0.18	—4.42
1925-1926	1,400	22,500	0.06	—4.97
1926-1927	4,700	25,000	0.19	—4.88
1927-1928	2,300	28,000	0.08	—2.36
1928-1929	1,900	30,550	0.06	—7.78
Averages, 1921-1929	2,800	21,200	0.13	—4.17

[1] Records for 1921, 1924, 1925 and 1929; other years interpolated.
[2] (—) indicates lowering of ground water level.

The total water supply tributary to this area is too small in relation to the draft to enable the fluctuations and supply to be plotted in a form that would indicate the inflow value required for zero fluctuation. Table 33 shows a continual lowering which tends to increase with the increase in irrigated area. For the last four years shown.

with an average irrigated area of about one-fourth of the gross area, an average lowering of about five feet per year has occurred. A larger lowering occurred in 1927 than in the very dry year of 1924, indicating that the area irrigated is the main factor causing lowering and that differences in the very limited tributary supply in individual years do not materially affect the results. An average annual depletion of about 50,000 acre-feet for the period, 1921–1929, has been estimated for the Earlimart-Delano Unit upon the basis of an assumed drainage factor of 12½ per cent applied to the total drained soil volume. The sum of the annual depletion and the average estimated annual run-off of White River indicates a use of 2.5 acre-feet per irrigated acre average for the eight-year period, and 1.7 acre-feet per acre irrigated in 1929.

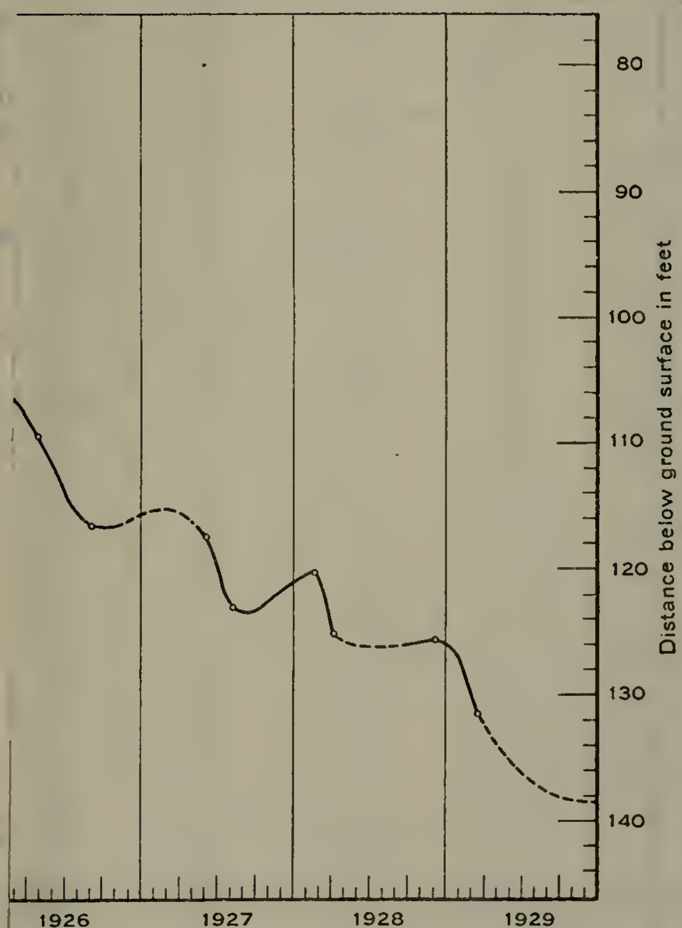
On Plate XVI, "Earlimart-Delano Ground Water Unit," is shown a profile extending east and west through Delano. This crosses the area of heavy pumping east of Delano. The relatively flat slope of the ground water in 1921, in comparison with the land slopes, illustrates the rapid increase of pumping lift to the east as well as the light slope of the ground water needed to discharge the naturally tributary supply. The profile for 1929 shows, clearly, the effect of pumping in this area. The lowering has produced a ground water depression which has reversed the ground water slope underlying the western portion of the unit. The plate also shows the hydrographs of two wells whose fluctuations are typical for this area. Well No. 24–26–29 and 24–26–30a, jointly, show the progress of lowering in the almost solidly developed area near Delano. The readings on these wells were not continuous, but sufficient were obtained to show that the steady decline is unaffected by the variations in stream flow in different years. These wells are remote from any stream channels. Well 24–26–9 is on the lower course of White River. A more rapid lowering occurred in the later years shown than at the beginning of the period. This is probably due to the larger area irrigated in later years. The record of water levels in this well does not show the effect which might be expected due to its proximity to the channel of White River. It lowered about as much in 1927 as in 1928 or 1929. The draft in this area is so large in relation to the supply that variations in the annual supply cause little if any change in the rate of lowering.

Tule-Deer Creek Unit.

This unit is bounded on the north by the Kaweah and Lindsay units, along the line of the Fifth Standard Parallel. It extends southward about sixteen miles to a line two miles north of Earlimart. The eastern limit is near Porterville and the western limit is four miles east of Angiola. Tule River and Deer Creek are the principal local tributary streams. The total area is 239,000 acres.

The available data on water supply, areas irrigated and ground water fluctuations are shown in Table 34. A total lowering in eight years of 22.6 feet has occurred. The conditions of water supply and irrigation vary in the different parts of this area. Canals diverting from Tule River serve lands near Porterville. The main portion of the run-off, particularly in years of less than normal run-off, is used in the upper portion of the Tule River Delta. Surplus water is

ELL 24-26-9



O GROUND WATER UNIT

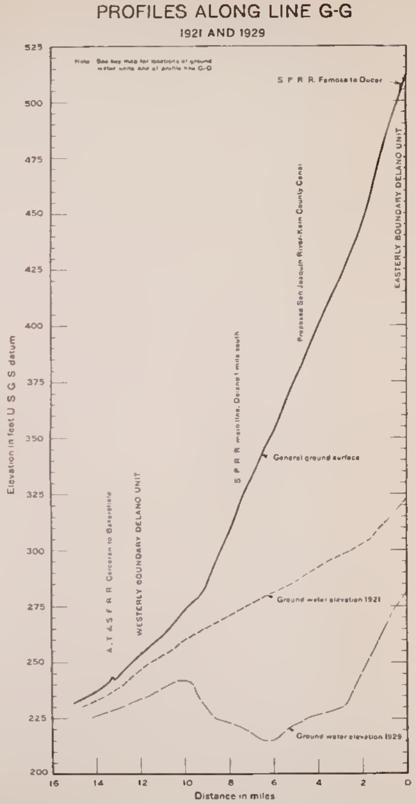
with an average irrigated area of about one-fourth of the gross area, an average lowering of about five feet per year has occurred. A larger lowering occurred in 1927 than in the very dry year of 1924, indicating that the area irrigated is the main factor causing lowering and that differences in the very limited tributary supply in individual years do not materially affect the results. An average annual depletion of about 50,000 acre-feet for the period, 1921–1929, has been estimated for the Earlimart-Delano Unit upon the basis of an assumed drainage factor of 12½ per cent applied to the total drained soil volume. The sum of the annual depletion and the average estimated annual run-off of White River indicates a use of 2.5 acre-feet per irrigated acre average for the eight-year period, and 1.7 acre-feet per acre irrigated in 1929.

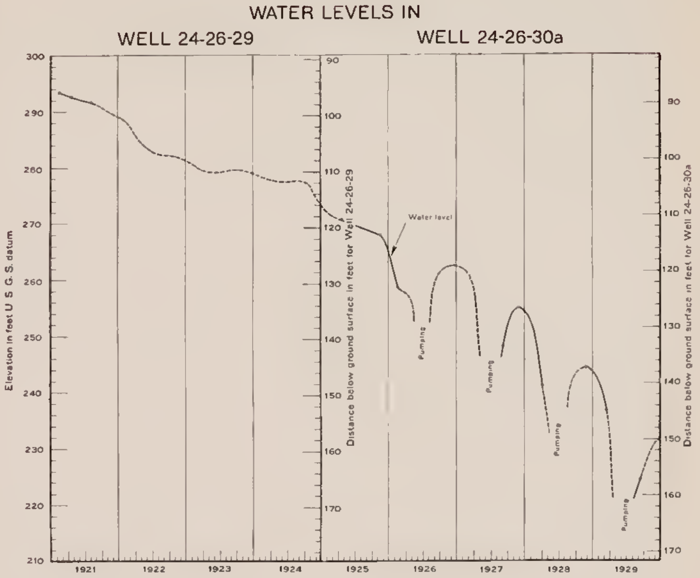
On Plate XVI, "Earlimart-Delano Ground Water Unit," is shown a profile extending east and west through Delano. This crosses the area of heavy pumping east of Delano. The relatively flat slope of the ground water in 1921, in comparison with the land slopes, illustrates the rapid increase of pumping lift to the east as well as the light slope of the ground water needed to discharge the naturally tributary supply. The profile for 1929 shows, clearly, the effect of pumping in this area. The lowering has produced a ground water depression which has reversed the ground water slope underlying the western portion of the unit. The plate also shows the hydrographs of two wells whose fluctuations are typical for this area. Well No. 24–26–29 and 24–26–30a, jointly, show the progress of lowering in the almost solidly developed area near Delano. The readings on these wells were not continuous, but sufficient were obtained to show that the steady decline is unaffected by the variations in stream flow in different years. These wells are remote from any stream channels. Well 24–26–9 is on the lower course of White River. A more rapid lowering occurred in the later years shown than at the beginning of the period. This is probably due to the larger area irrigated in later years. The record of water levels in this well does not show the effect which might be expected due to its proximity to the channel of White River. It lowered about as much in 1927 as in 1928 or 1929. The draft in this area is so large in relation to the supply that variations in the annual supply cause little if any change in the rate of lowering.

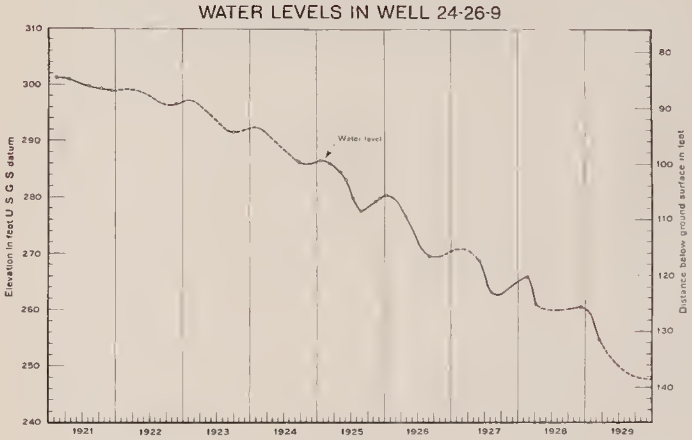
Tule-Deer Creek Unit.

This unit is bounded on the north by the Kaweah and Lindsay units, along the line of the Fifth Standard Parallel. It extends southward about sixteen miles to a line two miles north of Earlimart. The eastern limit is near Porterville and the western limit is four miles east of Angiola. Tule River and Deer Creek are the principal local tributary streams. The total area is 239,000 acres.

The available data on water supply, areas irrigated and ground water fluctuations are shown in Table 34. A total lowering in eight years of 22.6 feet has occurred. The conditions of water supply and irrigation vary in the different parts of this area. Canals diverting from Tule River serve lands near Porterville. The main portion of the run-off, particularly in years of less than normal run-off, is used in the upper portion of the Tule River Delta. Surplus water is







EARLIMART-DELANO GROUND WATER UNIT

80997

largely diverted to lower lands on the delta and larger flows result in some waste to Tulare Lake. There has been no surface outflow from Tule River from 1921 to 1929. Deer Creek has a small run-off. Pumping is carried on along its course by individual land owners and from a group of wells used to serve the Terra Bella Irrigation District, which also exercises a surface diversion right through the Deer Creek Ditch. For the remainder of this general area, there is no direct stream flow or canal use and any ground water replenishment is dependent on the slow outward movement of ground water from adjacent areas. The areas irrigated in 1921 and 1929 were determined from crop surveys, but for other years a uniform rate of increase in the irrigated area has been assumed.

An estimated average annual depletion of 56,000 acre-feet for the Tule-Deer Creek Unit is based upon the difference between the run-off and an indicated net use requirement for zero fluctuation of 2.2 acre-feet per acre for an average irrigated area of 67,400 acres. This gives an indicated average drainage factor of about eight per cent for the entire unit.

TABLE 34

TULE-DEER CREEK UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 373 square miles

Season	Water supply, in acre-feet			Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
	Tule River	Deer Creek	Total			
1920-1921	90,500	12,500	103,000	63,700	1.62	----------
1921-1922	139,700	16,900	156,600	64,500	2.43	—0.89
1922-1923	102,000	14,400	116,400	65,300	1.78	—1.27
1923-1924	24,700	4,950	29,650	66,100	0.45	—5.20
1924-1925	89,800	17,600	107,400	67,000	1.60	—1.87
1925-1926	48,900	7,550	56,450	67,800	0.83	—3.47
1926-1927	131,000	15,600	146,600	68,600	2.14	—1.60
1927-1928	48,200	8,900	57,100	69,400	0.82	—3.64
1928-1929	54,800	13,350	68,150	70,200	0.97	—4.70
Averages, 1921-1929	79,900	12,400	92,300	67,400	1.37	—2.83

[1] Data are available for 1921 and 1929 only. Values for other years interpolated.
[2] (—) indicates lowering of ground water.

In order to compare annual ground water fluctuations with water supply, the portions of this unit more directly dependent on Tule River and on Deer Creek have been separated. The relationship is not as direct as in other areas for which similar comparisons are made. The water supply is not distributed over much of the area which is dependent on these streams for such ground water replenishment as it may receive. The results are presented in Tables 35 and 36.

Table 35 gives the records for the area below Porterville which is more directly dependent on Tule River. The records of run-off of Tule River are reduced by the amount of the estimated use between the gaging stations and Porterville.

TABLE 35

TULE RIVER AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 155 square miles

Season	Water supply, run-off of Tule River at Porterville, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1921–1922	129,100	36,000	3.59	—0.02
1922–1923	91,400	37,000	2.47	—1.24
1923–1924	16,700	38,000	0.44	—4.57
1924–1925	79,800	39,000	2.05	—1.27
1925–1926	40,700	40,000	1.02	—4.69
1926–1927	120,400	41,000	2.94	—1.30
1927–1928	40,000	41,000	0.98	—5.19
1928–1929	46,600	41,000	1.14	—4.77
Averages, 1921–1929	70,600	39,100	1.80	—2.88

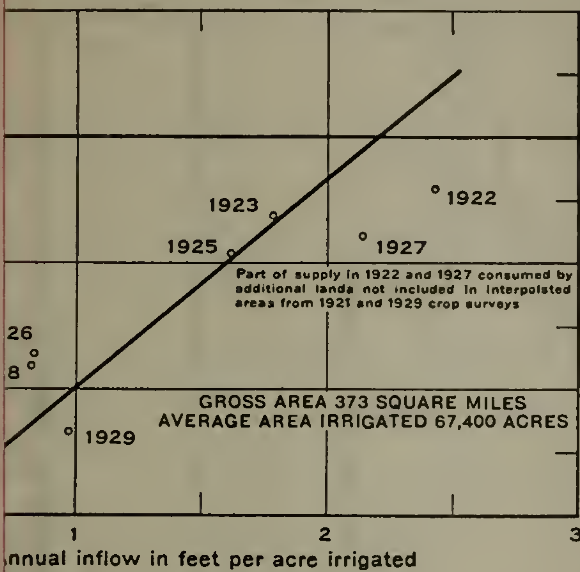
[1] Area irrigated based upon crop surveys for 1921 and 1929 and estimates contained in Bulletin No. 11, "Ground Water Resources of the Southern San Joaquin Valley," for 1924 and 1925.
[2] (—) indicates lowering of ground water.

The ground water fluctuations do not indicate the same relationship between supply and use as that found for other areas. The apparent rates of supply needed to maintain the ground water are larger than those found elsewhere. However, there are several elements involved which are considered to account for this difference. The crop area represents regularly cropped and cultivated lands. Larger winter flows may partially serve additional lands not included in the crop survey. Similar conditions occur in years of larger run-off in March and April, during which periods, stream flow is delivered to lower canals under the terms of a court decree governing such use. The crop area does not include the channel areas supporting natural vegetation which also consumes moisture. On the outer portions of the area, there may be a sufficient time lag between the occurrence of run-off and the resulting effect on the ground water so that the fluctuations of a given season may be partially the result of run-off of the preceding season. Therefore, it is believed that the indicated larger net use in this area is to be expected from consideration of these factors affecting its amount.

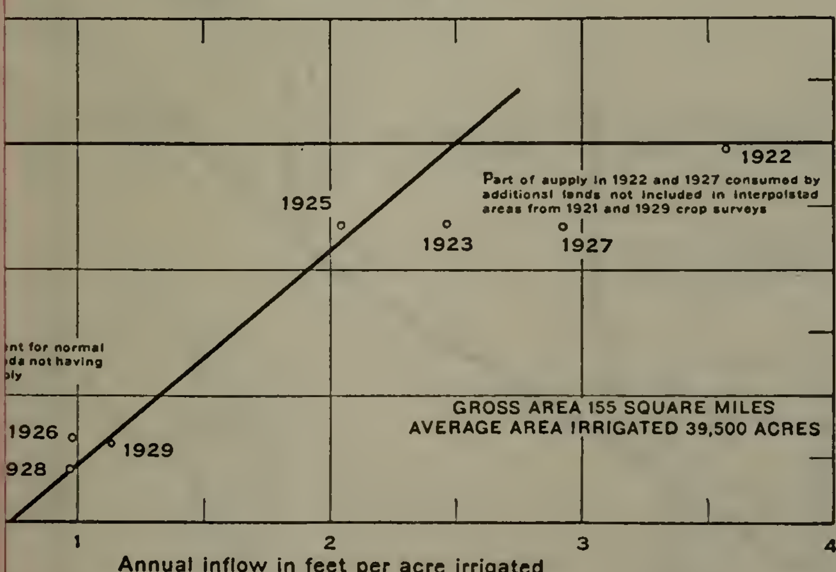
Table 36 gives the records of water supply, area irrigated and ground water changes for the Deer Creek area, below Terra Bella. These show a general relationship between supply and fluctuation. In no year has the supply been sufficient to maintain the ground water. The relation of inflow to change in level of ground water for Deer Creek area, as shown on Plate XVII, "Tule-Deer Creek Ground Water Unit," indicates that a supply of about two acre-feet per acre would meet the net use.

Plate X shows the total lowering that has occurred in the Tule-Deer Creek Unit from 1921 to 1929. Along Tule River the lowering varies from zero in a small area near Porterville to twenty-five feet in the western part of the irrigated area decreasing to ten feet in the lower river where there is only limited development. Along Deer Creek, west of Terra Bella, in the vicinity of the valley wells of the Terra Bella Irrigation District, the largest lowering, of about forty

LATION OF INFLOW TO
LEVEL OF GROUND WATER FOR
CREEK GROUND WATER UNIT



RELATION OF INFLOW TO
GE IN LEVEL OF GROUND WATER FOR
TULE RIVER AREA



TULE-DEER CREEK
GROUND WATER UNIT

TABLE 35

TULE RIVER AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 155 square miles

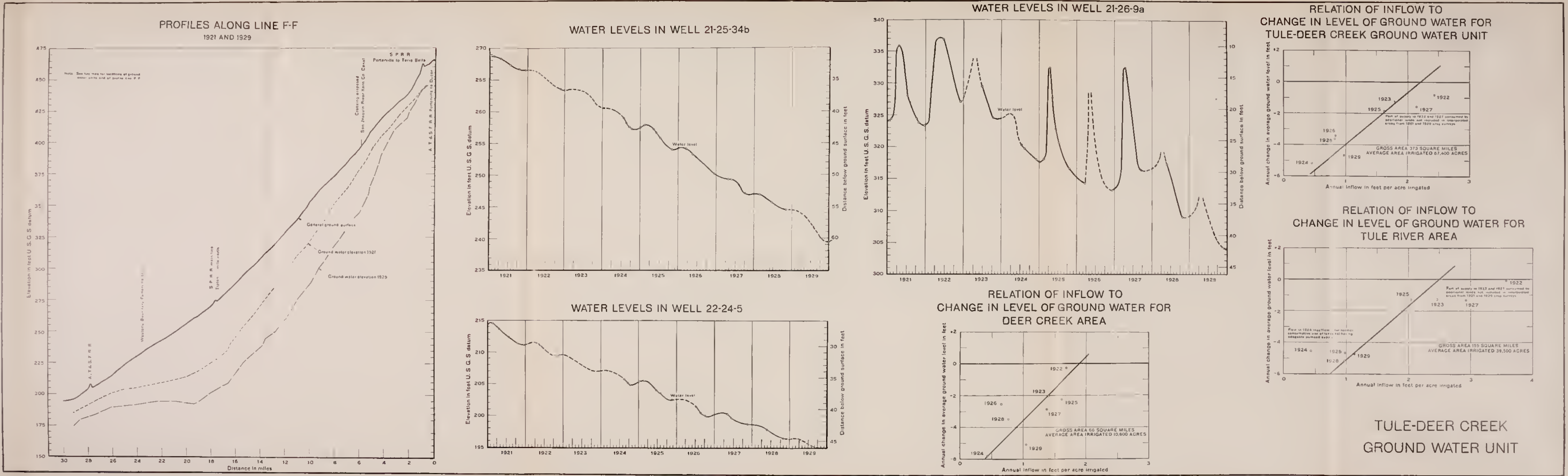
Season	Water supply, run-off of Tule River at Porterville, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1921-1922	129,100	36,000	3.59	—0.02
1922-1923	91,400	37,000	2.47	—1.24
1923-1924	16,700	38,000	0.44	—4.57
1924-1925	79,800	39,000	2.05	—1.27
1925-1926	40,700	40,000	1.02	—4.69
1926-1927	120,400	41,000	2.94	—1.30
1927-1928	40,000	41,000	0.98	—5.19
1928-1929	46,600	41,000	1.14	—4.77
Averages, 1921-1929	70,600	39,100	1.80	—2.88

[1] Area irrigated based upon crop surveys for 1921 and 1929 and estimates contained in Bulletin No. 11, "Ground Water Resources of the Southern San Joaquin Valley," for 1924 and 1925.
[2] (—) indicates lowering of ground water.

The ground water fluctuations do not indicate the same relationship between supply and use as that found for other areas. The apparent rates of supply needed to maintain the ground water are larger than those found elsewhere. However, there are several elements involved which are considered to account for this difference. The crop area represents regularly cropped and cultivated lands. Larger winter flows may partially serve additional lands not included in the crop survey. Similar conditions occur in years of larger run-off in March and April, during which periods, stream flow is delivered to lower canals under the terms of a court decree governing such use. The crop area does not include the channel areas supporting natural vegetation which also consumes moisture. On the outer portions of the area, there may be a sufficient time lag between the occurrence of run-off and the resulting effect on the ground water so that the fluctuations of a given season may be partially the result of run-off of the preceding season. Therefore, it is believed that the indicated larger net use in this area is to be expected from consideration of these factors affecting its amount.

Table 36 gives the records of water supply, area irrigated and ground water changes for the Deer Creek area, below Terra Bella. These show a general relationship between supply and fluctuation. In no year has the supply been sufficient to maintain the ground water. The relation of inflow to change in level of ground water for Deer Creek area, as shown on Plate XVII, "Tule-Deer Creek Ground Water Unit," indicates that a supply of about two acre-feet per acre would meet the net use.

Plate X shows the total lowering that has occurred in the Tule-Deer Creek Unit from 1921 to 1929. Along Tule River the lowering varies from zero in a small area near Porterville to twenty-five feet in the western part of the irrigated area decreasing to ten feet in the lower river where there is only limited development. Along Deer Creek, west of Terra Bella, in the vicinity of the valley wells of the Terra Bella Irrigation District, the largest lowering, of about forty



TULE-DEER CREEK
GROUND WATER UNIT

49997


CHANGE IN
CHANG

TABLE 36

DEER CREEK AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 66 square miles

Season	Water supply, run-off of Deer Creek at Terra Bella, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1921–1922	16,500	9,800	1.68	—0.38
1922–1923	14,200	10,100	1.40	—2.03
1923–1924	4,600	10,400	0.44	—5.80
1924–1925	17,200	10,700	1.61	—2.23
1925–1926	7,100	11,000	0.65	—2.55
1926–1927	15,100	11,000	1.37	—2.87
1927–1928	8,400	10,900	0.77	—3.51
1928–1929	11,300	10,800	1.05	—5.10
Averages, 1921–1929	11,800	10,600	1.11	—3.06

[1] Includes irrigated area to the east of the ground water unit assumed, for which ground water changes are available. Acreage based upon crop surveys for 1921 and 1929, and upon Terra Bella Irrigation District reports.
[2] (—) Indicates loweering of ground water level.

feet, has occurred. In the general area, between Tule River and Deer Creek, the lowering has varied from five to twenty-five feet near the east side to twenty to thirty-five feet for the remainder of the area east of Tipton and Pixley, with smaller amounts to the west.

A profile extending across Tule River area from Porterville to Tipton and thence southwest is shown on Plate XVII, "Tule-Deer Creek Ground Water Unit." Lowering from 1921 to 1929 has occurred throughout the length shown. The land on the eastern portion receives canal service but supplemental pumping is also generally practiced. Less lowering has occurred than in the lower portion near Tipton where there is no canal service and irrigation depends entirely on pumping. Pumping just west of Tipton has caused sufficient lowering to have reached the point of reversing the direction of ground water slope. There is less development at the western end of the profile.

On Plate XVII are included the hydrographs of three typical wells extending across the Tule River Delta. Well 21–26–9a is adjacent to Tule River in an area of mixed canal and pumping service. A sharp response to flow in Tule River is shown with a marked lowering after adjacent stream flow ceases. Rises occurred in 1922 and 1927, the only two years, in the period shown, in which the run-off was normal. While a total lowering of about 20 feet is shown for the eight years, it is probable that, in a series of years of normal run-off, ground water at this well would maintain itself. Well 21–25–34b is about three miles east of Tipton in an area of pumping development. It is about three miles south of the nearest channel of Tule River. It shows no response to stream flow but has followed a fairly steady rate of lowering of over three feet per year. Lowering in 1924 was similar to that in 1927. Under existing conditions, only continual lowering can be expected in this area. Well 22–24–5 is located four miles west of Tipton at the outer edge of pumping development and of the Tule River Delta. A steady lowering, unaffected by annual variations in run-off, is shown. An average annual rate of lowering of about two feet has occurred.

Kaweah Unit.

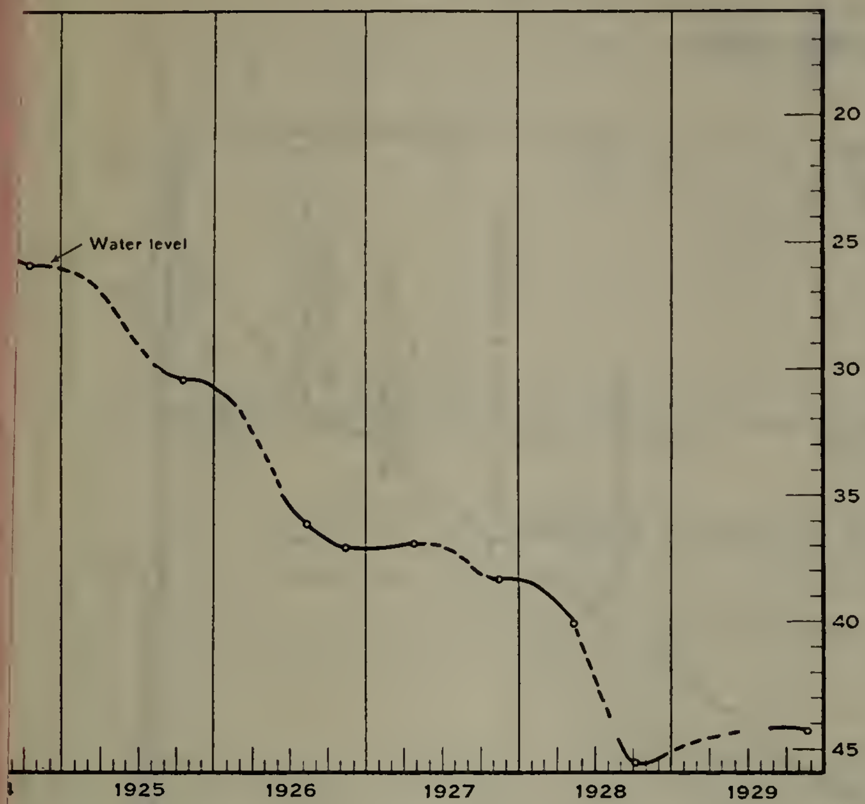
This unit includes that portion of the Kaweah River Delta served by surface waters from that stream. Its northern limit is at Cottonwood Creek and the southern limit two miles south of the Fifth Standard Parallel near Waukena. The eastern limit is about two miles east of Exeter and the western limit one mile east of the east line of Range 22 East at Waukena. The gross area is 468 square miles and the average area irrigated is 209 square miles, or 133,700 acres. While there are a few diversions between Three Rivers and McKay Point, the main use of Kaweah River occurs below McKay Point. Here the river divides into the St. Johns and Kaweah channels. The diversions by the individual canals are governed by their relative rights and priorities have been established through litigation. The larger and more dependable part of the stream flow is used mainly by the higher canals. As the low water flow of Kaweah River is much less than the demands of the total area irrigated, supplemental pumping is usual. Formerly much land secured its supplemental supply by subirrigation from high ground water. Lowering in recent years has necessitated pumping. The individual canals on Kaweah River serve generally small areas which are somewhat intermingled. Nearly all systems are organized as mutual water companies, an exception being the Tulare Irrigation District. The small size and overlapping of the different systems make it impractical to segregate the use and ground water fluctuations, by individual areas.

Plate X shows the changes in ground water from 1921 to 1929. Lowering has occurred throughout the Kaweah Delta except for a spot on the river near the hills and a spot on the north edge where there is practically no use of water. In the main canal served areas the general lowering has varied from five to fifteen feet. Away from canal service, lowering has varied with the extent of pumping draft. General lowering of about twenty feet around Ivanhoe, twenty to fifty feet near Exeter, thirty feet near Goshen, and twenty-five to thirty-five feet near Tulare illustrate results in areas of extensive pumping. Lowering of ten to twenty-five feet has occurred around the edges of the area.

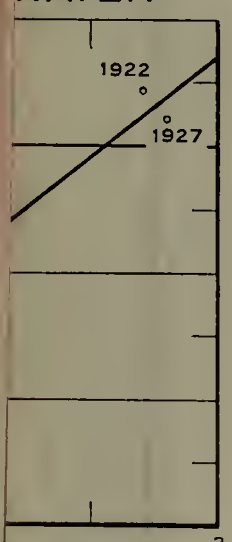
The data on water supply, areas irrigated and ground water changes for the entire area of the Kaweah Unit are given in Table 37. These show an average lowering over the whole area for the eight year period of 2.24 feet per year with an average supply of 1.88 acre-feet per acre irrigated. This area includes some lands adjacent to the Kaweah River but not supplied by it. Some additional areas toward which the ground water slopes from the Kaweah Delta are included in other areas. Accompanying graphs, a typical profile and hydrographs from records of typical wells are shown on Plate XVIII, "Kaweah Ground Water Unit."

An apparent average net use requirement of 2.56 acre-feet per acre for the average irrigated area of 133,700 acres in the Kaweah Unit is indicated, and the estimated average annual depletion of 92,000 acre-feet is based upon the difference between the indicated net use requirement and the mean net inflow of 250,800 acre-feet for the 1921–1929 period. This results in an indicated average drainage factor of about 14 per cent for this unit. This large apparent net use is due to several factors, some of which are: (1) the use of water (not deducted from the inflow) by lands to the east of the ground water unit which are

EVELS IN WELL 19-23-21b



CHANGE
WATER



ated

KAWEAH
GROUND WATER UNIT

Kaweah Unit.

This unit includes that portion of the Kaweah River Delta served by surface waters from that stream. Its northern limit is at Cottonwood Creek and the southern limit two miles south of the Fifth Standard Parallel near Waukena. The eastern limit is about two miles east of Exeter and the western limit one mile east of the east line of Range 22 East at Waukena. The gross area is 468 square miles and the average area irrigated is 209 square miles, or 133,700 acres. While there are a few diversions between Three Rivers and McKay Point, the main use of Kaweah River occurs below McKay Point. Here the river divides into the St. Johns and Kaweah channels. The diversions by the individual canals are governed by their relative rights and priorities have been established through litigation. The larger and more dependable part of the stream flow is used mainly by the higher canals. As the low water flow of Kaweah River is much less than the demands of the total area irrigated, supplemental pumping is usual. Formerly much land secured its supplemental supply by subirrigation from high ground water. Lowering in recent years has necessitated pumping. The individual canals on Kaweah River serve generally small areas which are somewhat intermingled. Nearly all systems are organized as mutual water companies, an exception being the Tulare Irrigation District. The small size and overlapping of the different systems make it impractical to segregate the use and ground water fluctuations, by individual areas.

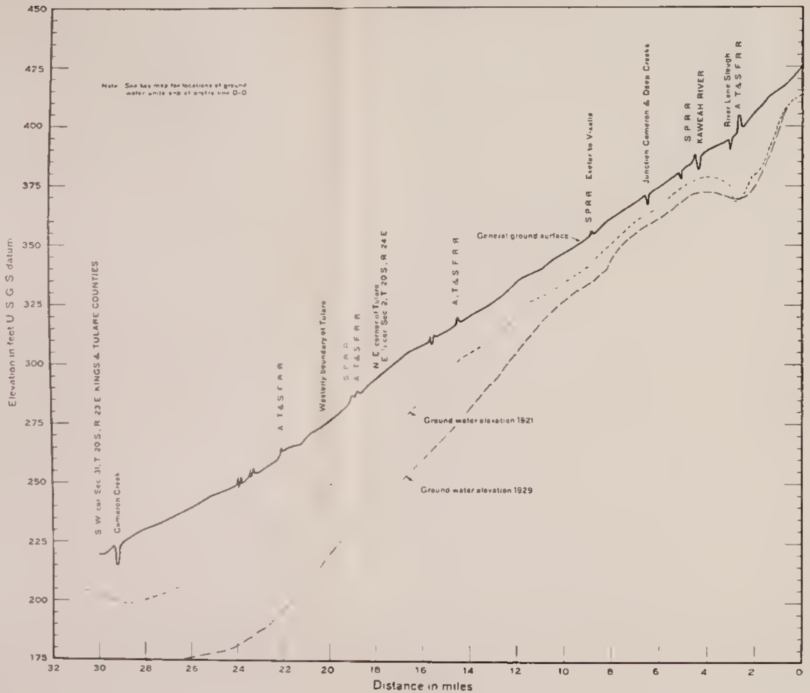
Plate X shows the changes in ground water from 1921 to 1929. Lowering has occurred throughout the Kaweah Delta except for a spot on the river near the hills and a spot on the north edge where there is practically no use of water. In the main canal served areas the general lowering has varied from five to fifteen feet. Away from canal service, lowering has varied with the extent of pumping draft. General lowering of about twenty feet around Ivanhoe, twenty to fifty feet near Exeter, thirty feet near Goshen, and twenty-five to thirty-five feet near Tulare illustrate results in areas of extensive pumping. Lowering of ten to twenty-five feet has occurred around the edges of the area.

The data on water supply, areas irrigated and ground water changes for the entire area of the Kaweah Unit are given in Table 37. These show an average lowering over the whole area for the eight year period of 2.24 feet per year with an average supply of 1.88 acre-feet per acre irrigated. This area includes some lands adjacent to the Kaweah River but not supplied by it. Some additional areas toward which the ground water slopes from the Kaweah Delta are included in other areas. Accompanying graphs, a typical profile and hydrographs from records of typical wells are shown on Plate XVIII, "Kaweah Ground Water Unit."

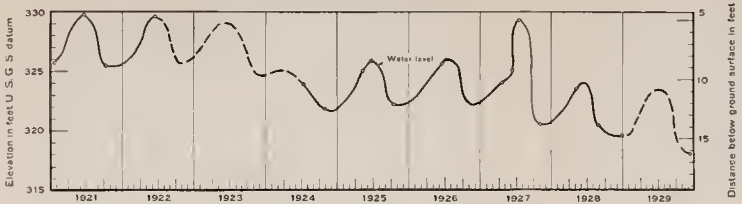
An apparent average net use requirement of 2.56 acre-feet per acre for the average irrigated area of 133,700 acres in the Kaweah Unit is indicated, and the estimated average annual depletion of 92,000 acre-feet is based upon the difference between the indicated net use requirement and the mean net inflow of 250,800 acre-feet for the 1921–1929 period. This results in an indicated average drainage factor of about 14 per cent for this unit. This large apparent net use is due to several factors, some of which are: (1) the use of water (not deducted from the inflow) by lands to the east of the ground water unit which are

PROFILES ALONG LINE D-D

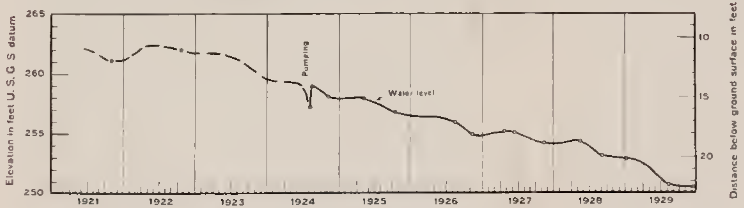
1921 AND 1929



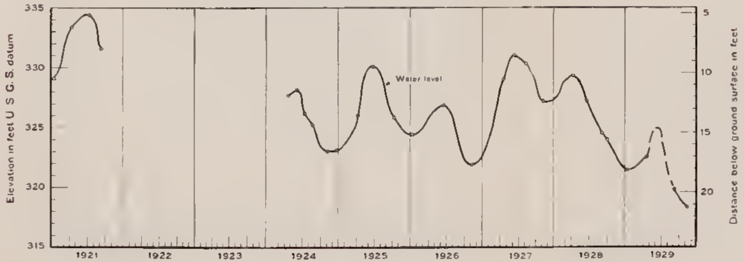
WATER LEVELS IN WELL 18-25-4a



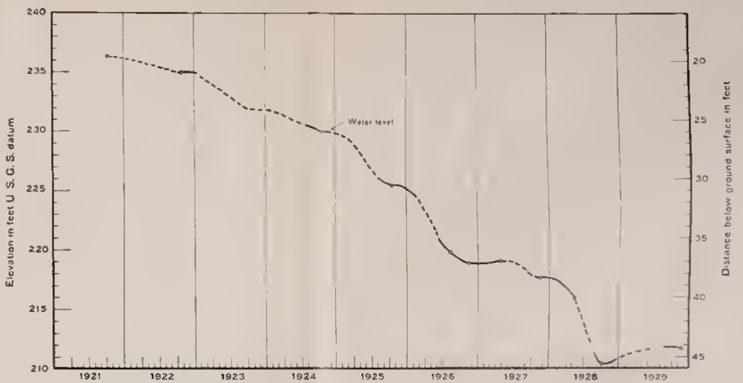
WATER LEVELS IN WELL 18-23-11



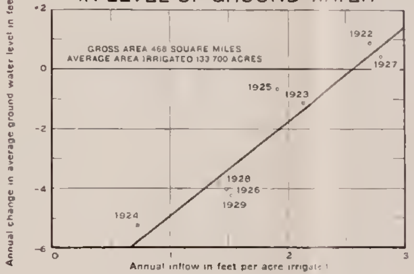
WATER LEVELS IN WELL 18-25-34a



WATER LEVELS IN WELL 19-23-21b



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER



KAWEAH

GROUND WATER UNIT

not included in the irrigated areas, (2) the subirrigation and flooding in years of large flow of lands not included in the irrigated areas, (3) the underground outflow to lands in the west part of the Lindsay Unit, (4) possible underground outflow to areas to the west of the selected ground water unit, (5) consumption of water by natural vegetation.

TABLE 37

KAWEAH UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 468 square miles

Season	Water supply			Area irrigated, in acres[2]	Seasonal net supply, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[3]
	Run-off of Kaweah River at Three Rivers, in acre-feet	Outflow not used on Kaweah Delta, in acre-feet[1]	Net supply for Kaweah Delta, in acre-feet			
1921–1922	461,100	83,800	377,300	140,000	2.70	+0.88
1922–1923	363,500	63,800	299,700	141,000	2.12	—1.19
1923–1924	101,700	13,700	88,000	120,000	0.73	—5.21
1924–1925	325,500	51,300	274,200	143,000	1.92	—0.68
1925–1926	218,800	33,800	185,000	124,000	1.49	—4.05
1926–1927	483,200	78,000	405,200	145,000	2.79	+0.41
1927–1928	203,000	20,900	182,100	128,000	1.42	—3.86
1928–1929	222,800	28,000	194,800	128,500	1.52	—4.26
Averages, 1921–1929	297,500	46,700	250,800	133,700	1.88	—2.25

[1] Outflow from Lindsay-Strathmore Irrigation District well field on Rancho de Kaweah and 1929 exportation of Watchumna Ditch water, Lakeside Ditch water and estimated outflow through Cross Creek.
[2] Field surveys of irrigated lands were made in 1920 and 1929. Areas for intermediate seasons were estimated by interpolation for areas having adequate facilities for ground water utilization, and in accordance with available surface supplies and consideration of existing water right schedules for other areas.
[3] (+) indicates a rise, and (—) a fall in ground water level.

In order to compare the inflow and fluctuations more directly, the area below McKay Point dependent on Kaweah River was used. This agrees approximately with the area shown as the Kaweah Unit on Plate XII, but excludes lands above McKay Point and includes part of the Lindsay Unit. The results for this area are shown in Table 38.

TABLE 38

WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES FOR KAWEAH DELTA BELOW McKAY POINT

Gross area, 453 square miles

Season	Water supply. Inflow at McKay Point less outflow given in Table 37, in acre-feet	Area irrigated, in acres	Seasonal net inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1920–1921	258,800	131,700	1.97	[1]—1.05
1921–1922	364,000	134,100	2.71	+0.50
1922–1923	274,000	133,700	2.05	—0.77
1923–1924	69,600	108,300	0.64	—5.05
1924–1925	268,400	135,500	1.98	—1.20
1925–1926	175,800	113,900	1.54	—4.25
1926–1927	362,800	137,200	2.64	+0.17
1927–1928	160,400	114,800	1.40	—3.82
1928–1929	180,200	117,800	1.53	—4.76
Averages, 1921–1929	231,900	124,400	1.86	—2.40

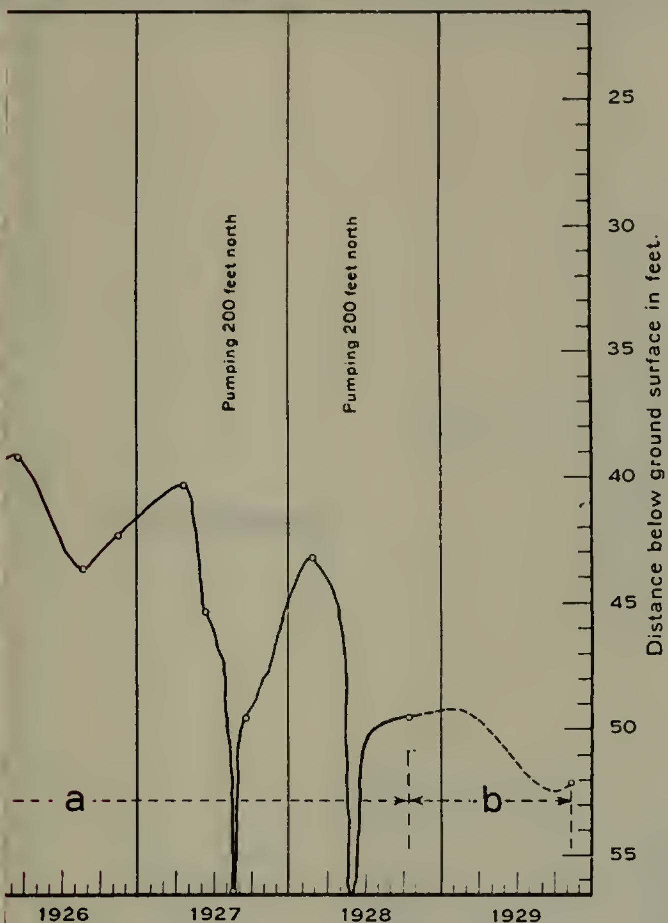
[1] Approximate—records incomplete; not included in mean.
[2] (+) indicates a rise and (—) a fall in ground water level.

The irrigated areas in Table 38 represent only the cropped areas. In addition, there are areas along the channels supporting trees and pasture which also consume water, and in years of larger run-off additional lands receive partial service for pasturage. Definite data regarding the extent of these areas are not available. They are sufficient to be a factor in such years as 1922 and 1927. The average net water supply is plotted against the ground water changes on Plate XIX, "Kaweah and Lindsay Ground Water Units." The normal relationship between supply and change is considered to be represented by the line shown. This line is based on the years 1921, 1923, 1925, 1926, 1928 and 1929. For 1922 and 1927 the additional lands flooded would reduce the supply per acre if the amount of such land were known and added to the cropped area and bring the points for these years, shown on the graph, into closer agreement with the results for other years. In 1924 the stream flow was insufficient to supply the full needs of the cropped areas not equipped for pumping and the smaller indicated net use is due to this shortage. For years in which cropped lands receive a normal supply, an inflow of 2.17 acre-feet per acre of cropped area appears to be needed to meet net use requirements and maintain the ground water. This includes actual moisture use on cropped lands and on the normal areas of channel lands not included in the cropped areas, and takes account of any lack of balance between unmeasured inflow and outflow. The result is somewhat larger than that obtained for areas in the Fresno Consolidated and Alta districts on Kings River. This difference is consistent with the conditions, as these district areas do not include extensive channel lands and the proportion of the areas planted to alfalfa is smaller than that on the Kaweah River Delta. If channel lands are held to their present area and additional lands are not partially supplied in years of larger run-off, the analyses indicate that an acre of irrigated crop can be supplied for each 2.17 acre-feet retained on this area. If the excess, in years of normal or larger run-off, is used on additional areas the number of acres of permanent crops which can be supported will be reduced in proportion to such additional use.

Profile D-D, on Plate XVIII, extends southwesterly across the Kaweah Delta. The upper portion follows the river in an area of heavy pumping, the effect of which shows on the profile. Below this area, the profile crosses the main canal served lands. While development here is extensive, the more direct canal supply has maintained the ground water with only limited lowering, even during the period of less than normal run-off. In the lower portion of the profile, there is little canal service although there are extensive areas depending on pumping. The greater distance from sources of direct supply and heavy draft has resulted in a lowering of over 30 feet during the eight-year period.

Profile E-E on Plate XIX extends east and west through the area between the deltas of Kaweah and Tule rivers, near Lindsay, and across the outer Kaweah Delta into the lower part of the South Kings area. The reversed ground water slopes caused by the heavy draft in the inter-delta area at the east are clearly illustrated by this profile. Near Elk Bayou the more direct canal supply has maintained the ground water with limited lowering even in recent dry years. The western

.S 20-26-17 a-b-c



KAWEAH AND LINDSAY
GROUND WATER UNITS

8

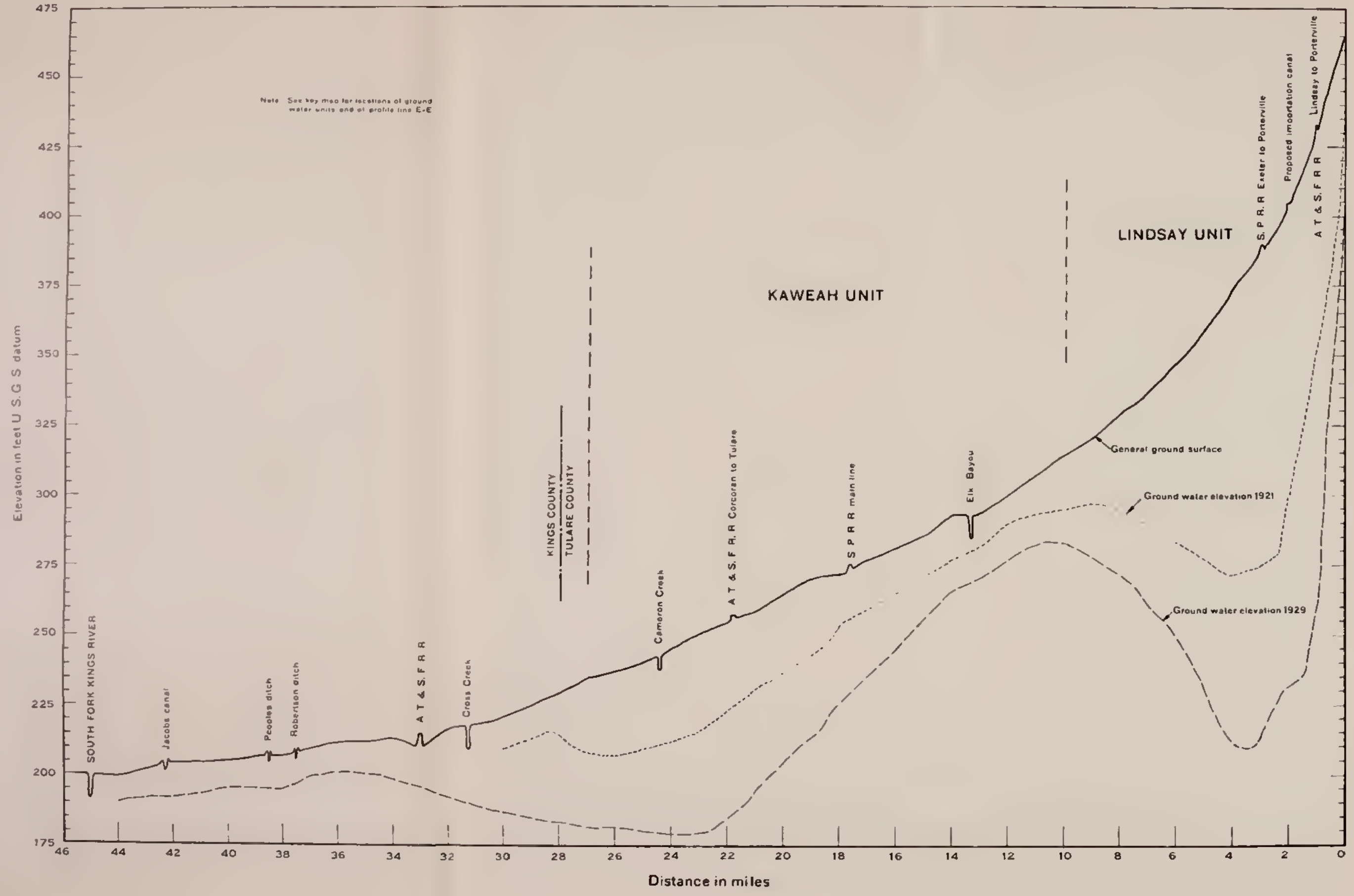
The irrigated areas in Table 38 represent only the cropped areas. In addition, there are areas along the channels supporting trees and pasture which also consume water, and in years of larger run-off additional lands receive partial service for pasturage. Definite data regarding the extent of these areas are not available. They are sufficient to be a factor in such years as 1922 and 1927. The average net water supply is plotted against the ground water changes on Plate XIX, "Kaweah and Lindsay Ground Water Units." The normal relationship between supply and change is considered to be represented by the line shown. This line is based on the years 1921, 1923, 1925, 1926, 1928 and 1929. For 1922 and 1927 the additional lands flooded would reduce the supply per acre if the amount of such land were known and added to the cropped area and bring the points for these years, shown on the graph, into closer agreement with the results for other years. In 1924 the stream flow was insufficient to supply the full needs of the cropped areas not equipped for pumping and the smaller indicated net use is due to this shortage. For years in which cropped lands receive a normal supply, an inflow of 2.17 acre-feet per acre of cropped area appears to be needed to meet net use requirements and maintain the ground water. This includes actual moisture use on cropped lands and on the normal areas of channel lands not included in the cropped areas, and takes account of any lack of balance between unmeasured inflow and outflow. The result is somewhat larger than that obtained for areas in the Fresno Consolidated and Alta districts on Kings River. This difference is consistent with the conditions, as these district areas do not include extensive channel lands and the proportion of the areas planted to alfalfa is smaller than that on the Kaweah River Delta. If channel lands are held to their present area and additional lands are not partially supplied in years of larger run-off, the analyses indicate that an acre of irrigated crop can be supplied for each 2.17 acre-feet retained on this area. If the excess, in years of normal or larger run-off, is used on additional areas the number of acres of permanent crops which can be supported will be reduced in proportion to such additional use.

Profile D-D, on Plate XVIII, extends southwesterly across the Kaweah Delta. The upper portion follows the river in an area of heavy pumping, the effect of which shows on the profile. Below this area, the profile crosses the main canal served lands. While development here is extensive, the more direct canal supply has maintained the ground water with only limited lowering, even during the period of less than normal run-off. In the lower portion of the profile, there is little canal service although there are extensive areas depending on pumping. The greater distance from sources of direct supply and heavy draft has resulted in a lowering of over 30 feet during the eight-year period.

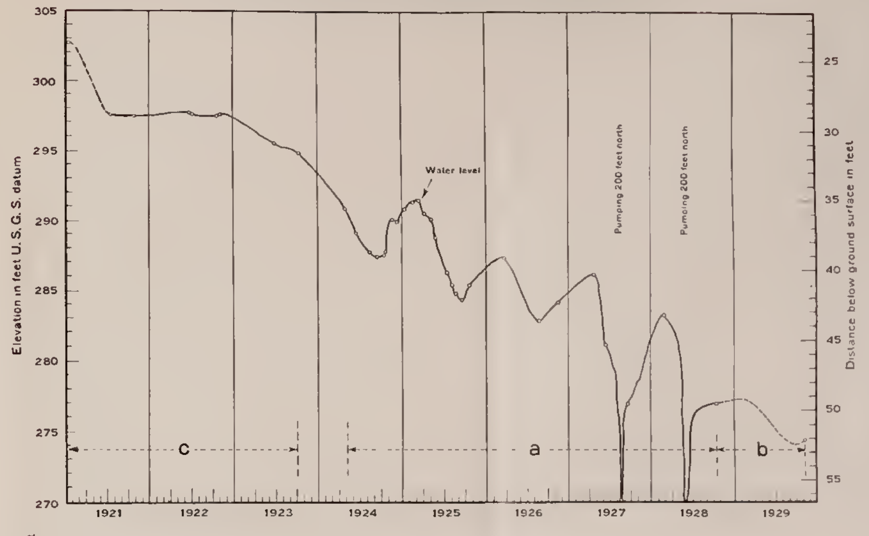
Profile E-E on Plate XIX extends east and west through the area between the deltas of Kaweah and Tule rivers, near Lindsay, and across the outer Kaweah Delta into the lower part of the South Kings area. The reversed ground water slopes caused by the heavy draft in the inter-delta area at the east are clearly illustrated by this profile. Near Elk Bayou the more direct canal supply has maintained the ground water with limited lowering even in recent dry years. The western

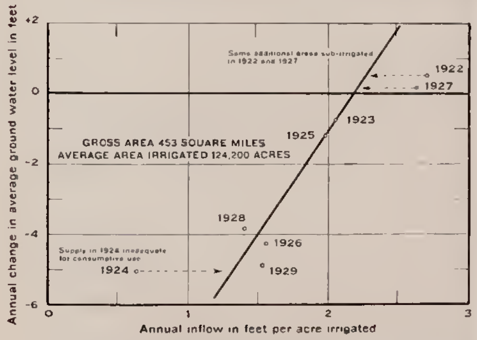
PROFILES ALONG LINE E-E

1921 AND 1929



WATER LEVELS IN WELLS 20-26-17 a-b-c

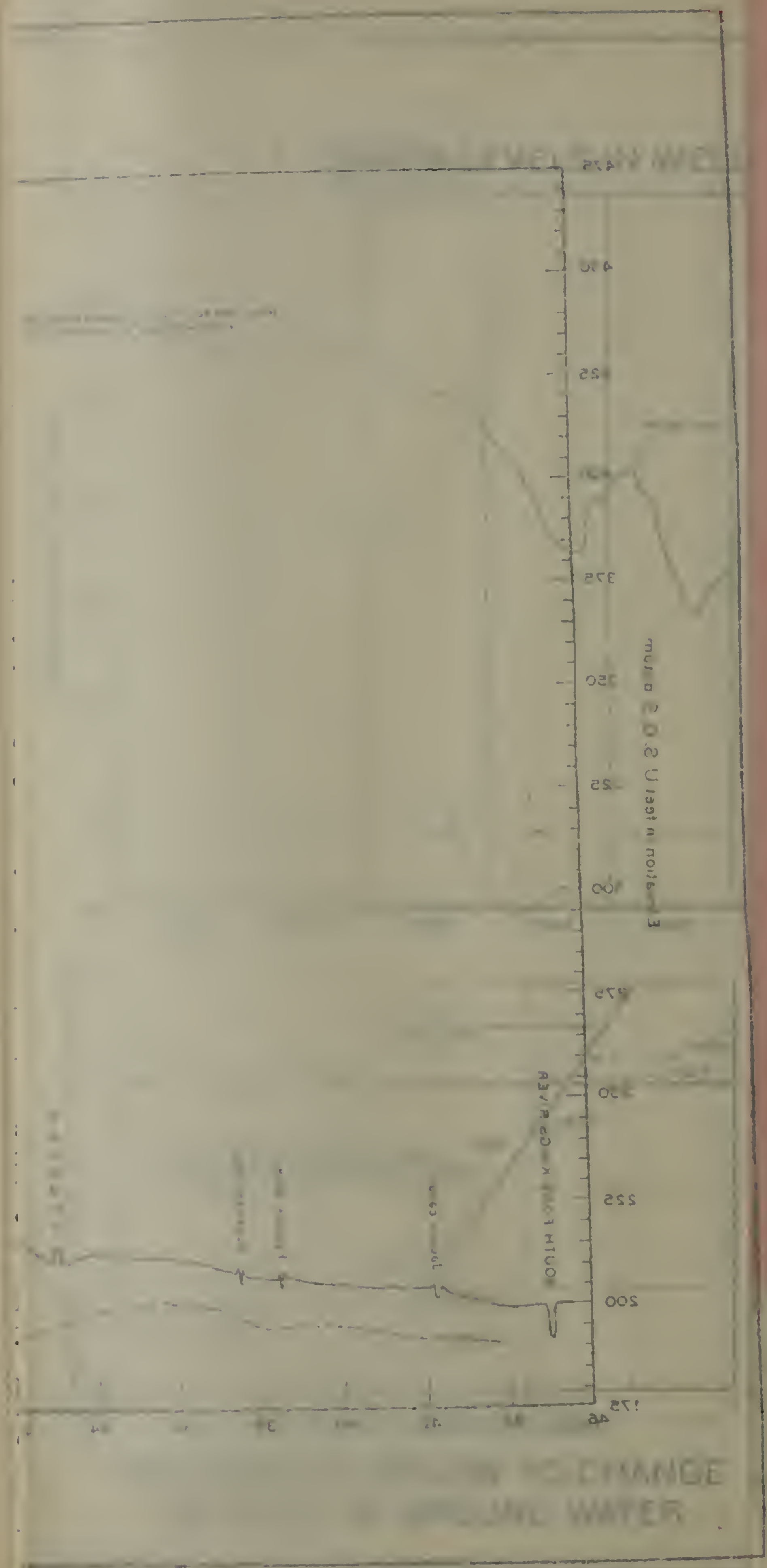




RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER

KAWEAH AND LINDSAY GROUND WATER UNITS

80997



and lower part of the Kaweah Delta shows similar heavy lowering to that shown on Profile D-D on Plate XVIII. On this plate are shown the hydrographs of four wells whose fluctuations illustrate the effect of supply and draft on the ground water. Well No. 18–25–4a is located in the northern part of the Kaweah Delta in an area of scattered canal and pumping service. A quite regular cycle of fluctuation is shown with a rise during the early summer and a decline during the period of low stream flow in the late summer. A total lowering of about seven feet for the eight-year period is shown. Well No. 18–25–34a is near Visalia within the area of canal service. In 1921 water rose in this well to within six feet of the ground surface. It did not fail to remain at more than 10 feet below the ground surface until the latter part of 1928. In 1929 lowering to more than 20 feet below the ground surface occurred. Well No. 18–23–11 is in the outer part of the Kaweah Delta, near Goshen, in an area receiving mainly flood water service and having little pumping development. A continuous and steady lowering, with little response to periods of larger river or canal flow, is shown. The rate of lowering shows little change either in greater than normal years like 1922 and 1927 or in dry years like 1924 or 1929. The lowering is probably the slowly accumulative effect of the general lack of balance between inflow and draft. Well No. 19–23–21b is also in the outer Kaweah Delta in an area of little pump or canal service. The record is incomplete, but indicates a total lowering of about 25 feet in the eight years.

Lindsay Unit.

This includes the area at the eastern rim of the San Joaquin Valley between the deltas of Kaweah and Tule rivers. It includes a large portion of the Lindsay-Strathmore Irrigation District and all of Township 20 South, Range 26 East. The gross area is 64 square miles and the irrigated area 22,000 acres. It is devoted largely to citrus culture. Pumping in this area was among the earliest uses of ground water for irrigation in the San Joaquin Valley. Such pumping resulted in rapid ground water lowering. The increase in salt content with lowering of the ground water, in some areas, rendered the wells unsuited to use. These conditions resulted in the organization of the Lindsay-Strathmore Irrigation District for the purpose of securing outside water of suitable quantity and quality. This district has a gross area of 15,250 acres of which 7800 acres, largely in citrus, were irrigated in 1929. The area here described, of which the Lindsay-Strathmore Irrigation District is a part, has a gross area of 41,216 acres and extends to the west of the Lindsay-Strathmore District. Approximately 22,000 acres of this combined area were irrigated in 1929. This area occupies the higher valley lands against the adjacent foothill slopes in a locality where there are no locally tributary streams of more than nominal run-off. It is relatively distant from the Kaweah and Tule rivers and out of the direction of the main ground water movement of their respective units. This lack of active sources of ground water replenishment is shown by the rapid rate of lowering that has occurred.

The available data on water supply and ground water fluctuations are shown in Table 39.

TABLE 39

LINDSAY UNIT—WATER SUPPLY AND GROUND WATER CHANGES

(22,000 acres irrigated in 1929)
Gross area, 64 square miles

Season	Water supply, inflow from Kaweah unit, in acre-feet	Seasonal average change of ground water level, in feet[1]
1921–1922	13,400	— 1.62
1922–1923	14,100	— 4.33
1923–1924	13,700	—10.01
1924–1925	12,700	— 2.50
1925–1926	14,100	— 9.01
1926–1927	13,300	— 3.17
1927–1928	14,300	— 5.17
1928–1929	15,500	—18.97
Averages, 1921–1929	13,900	— 6.85

[1] (—) indicates lowering of ground water.

The ground water fluctuations do not vary directly with the supply from Kaweah River. The locally tributary run-off, principally from Lewis Creek, is small and widely variable in different years. Supplemental pumping is used and the ground water fluctuations probably reflect the amount of such pumping more directly than variations in local run-off. The inadequacy of local ground water supplies for local areas was demonstrated prior to the construction of systems based on the use of outside sources. The total supply is too small in relation to the draft and the depth to ground water too great to permit the application of the general graphical method of determining the value of net use per acre. An estimated average annual depletion of 19,000 acre-feet for the 1921–1929 period is based upon an assumed drainage factor of about 7 per cent.

Wells 20–26–17a, b and c, Plate XIX, are located at the west side of the Lindsay area about three miles from Elk Bayou. Adjacent irrigation is dependent entirely on pumping as there is no canal service in the vicinity of this well. A continuous general lowering is shown. A rise occurs during the winter, which was as large in 1924 as in 1925 or 1926. Such rise represents general recovery during the period of minimum pumping draft. The ground water movement into this area, under the slope produced by the local lowering, does not appear to have increased so as to be sufficient to maintain present draft.

Ground water profile E-E through this area is shown on Plate XIX. The marked ground water depression illustrates the result of pumping in areas remote from sources of direct replenishment. The total lowering from 1921 to 1929 as shown on Plate XI varies generally from 25 to 75 feet and averages 45 feet. The greatest lowering has occurred in the areas of heaviest development.

Kings River Areas.

Kings River is the source of water supply for a large area served by several different canal systems. The relative priority of diversion right of the different canals varies, so that there are wide differences in the character and amount of supply received. Use varies from a fairly complete service, both in amount and distribution during the season, to flood water practice utilizing water at the occasional times at which it may be available. No storage has as yet been constructed on the Kings River. A site is available at Pine Flat and preliminary steps toward organization for its construction have been taken. Some storage occurs at times in Tulare Lake. Kings River flow divides on the crest of its delta, part flowing north through Fresno Slough to the San Joaquin River and part to the south into Tulare Lake. Tulare Lake is formed by the ridge which Kings River has built across the valley. As the low water flow of Kings River is insufficient to meet the demands during the late summer months, of the lands now developed, extensive pumping from the ground water is practiced in several of the areas served. Such pumping is more general in the upper areas.

Diversions from Kings River since 1918 have been measured by a water master representing the State or the Kings River Water Association. During the later portion of the period such diversions have been under the general control of the water master operating under a schedule of diversions agreed upon by the larger part of the water right interests. This schedule specifies the amount of diversion to which each canal is entitled at river stages extending to river flows of 9450 cubic feet per second in the months of maximum demand. Rights are claimed at higher stages but are not scheduled. The work of the water master makes available an unusually complete record of practically all diversions from Kings River since 1918. The diversion schedule varies in the different months. In June, the month of maximum schedule rights, the entitlements total 9000 second-feet. The schedule shows the diversion which each canal may make for variations in mean daily stream flow of 100 second-feet. The amounts of these diversions for a few stages of the river in June are shown in Table 40. The difference between the river stage and the total schedule

TABLE 40

SUMMARY OF KINGS RIVER SCHEDULE FOR JUNE

Schedule of 1928

Diversion	Schedule for each diversion				
	River stage, mean daily flow, in second-feet				
	1000	2000	5000	7000	9000
Laguna	15	15	300	400	425
Fresno	650	1,300	1,450	1,450	1,475
Lemoore	91	155	275	375	450
Peoples	183	310	450	500	525
Last Chance	46	155	225	325	325
Consolidated		50	1,100	1,400	1,500
Alta			1,000	1,100	1,200
Murphy Slough	15	15	200	325	375
Liberty				100	100
Crescent				175	175
Stinson				175	200
Burrel				75	150
James				150	150
Beta Main				125	125
Heinlen				70	170
Lakelands					450
Total schedule diversions	1,000	2,000	5,000	6,745	7,795

diversions for the higher stages represents diversions not included in the schedule.

Table 41 shows the records of diversion and run-off for each of the years from 1922 to 1929, inclusive. In 1927 the run-off was about normal. In 1924, 1928 and 1929 it was much below normal. The effect of deficient run-off on the diversions of these canals is shown clearly.

TABLE 41

DIVERSIONS BY KINGS RIVER CANALS, 1922 TO 1929

From Reports of Kings River Water Master; Flow of Kings River at Piedra, below Empire Weir No. 2, and at Burrel

District or area	Canals	Acre-feet per year 1922	1923	1924	1925	1926	1927	1928	1929	8 year mean	Area of class 1 and class 2 lands, in acres	Area irrigated in 1929, in acres
Alta	Alta	168,682	163,472	14,961	158,854	128,015	255,198	98,095	85,448	134,091	102,308	68,450
Consolidated	Consolidated[1]	260,825	228,476	28,397	216,091	167,273	330,144	135,074	125,594	186,484	146,940	129,000
	Emigrant[2]	9,461	6,843	0	1,048	1,731	3,566	0	0	2,831		
Fresno	Fresno and Gould[3]	367,181	377,297	176,592	423,462	326,952	459,215	324,134	324,633	347,433	230,216	192,800
Peoples	Peoples[4]	173,075	149,073	83,021	170,403	128,791	217,131	119,067	100,527	142,636	51,198	23,400
Lucerne	Last Chance	56,896	63,716	18,238	63,625	52,402	97,125	46,262	36,456	54,340	31,279	19,556
Lemoore	Lemoore	142,052	.125,137	48,333	94,891	81,527	119,498	70,305	59,643	92,673	47,071	14,574
Island No. 3	Island No. 3 (from Fresno)[5]	5,500	2,943	0	4,499	3,021	6,903	2,484	2,409	3,470	4,620	3,720
Liberty	Liberty	14,973	11,174	60	3,097	4,585	14,338	2,261	2,271	6,595	4,000	*1,000
Murphy Slough area[6]	Big and Little Mill Race	26,011	18,633	3,231	11,078	[7]13,113	29,075	10,273	[7]8,127	14,942	10,700	6,780
	Reed	6,643	6,606	1,795	4,983	5,492	9,357	3,516	3,032	5,178		
	Turner-Riverdale	26,612	29,069	5,243	18,410	19,884	38,401	12,109	10,571	20,038	15,198	8,640
Burrell	Cuthbert-Burrel	[8]5,000	[8]2,700	0	1,867	1,440	0	0	0	1,376	9,542	3,740
Laguna	A, Grant, Island, and Summit Lake	65,313	67,621	10,810	48,156	51,597	74,734	30,803	26,586	46,952	28,666	22,500
Crescent	Crescent and Calamity	[9]17,000	21,124	0	9,879	8,661	21,179	4,786	3,870	10,812	8,545	2,894
Stinson	Stinson	11,947	16,712	0	7,185	10,142	13,544	1,194	986	7,714	11,750	5,984
Stratford	Empire No. 1 and No. 2	10,570	10,914	0	1,521	5,496	[7]11,000	0	0	4,938	*125,000	[10]75,000
Tulare Lake vicinity	Blakeley (Empire No. 3)	36,997	11,440	0	2,299	827	38,972	0	0	11,317		
Corcoran (Lakeland)	Lakeland[11]	32,922	13,446	0	2,944	8,303	20,075	0	0	9,711		
Lakeland	Tulare Lake (Empire No. 4[11])	[7]25,945	13,400	0	[7]0	[7]0	25,591	0	0	8,117		
James	James and ⅓ of Beta Main	16,658	18,624	0	2,531	6,510	28,359	0	0	9,085	23,795	11,640
Tranquillity	⅔ of Beta Main	14,738	12,085	0	2,075	3,786	10,826	0	0	5,439	10,210	6,700
Subtotals		1,495,001	1,370,499	390,681	1,248,898	1,029,548	1,824,231	860,363	790,153	1,126,172	861,038	596,378
Flow at Burrel, less diversions of Beta Main and James canals		513,037	138,558	0	7,640	16,549	125,191	0	0	100,122		
Flow toward Tulare Lake, below Empire Weir No. 2		196,711	28,692	0	0	0	6,869	0	0	29,034		
Consumptive use on 10,000 to 15,000 acres, absorption, inflow[12]		16,951	—37,449	8,819	26,462	52,903	27,109	34,037	47,047	21,860	20,000	*12,000
Total flow at Piedra		2,220,700	1,500,300	399,500	1,283,000	1,099,000	1,983,400	894,400	837,200	1,277,188	881,038	608,378

[1] Water master's measurements revised by adding inflow of Lone Tree Canal and deducting outflow to China Slough and Island No. 3 canals in accord with estimates obtained from Consolidated Irrigation District records.

[2] 68.75 per cent of Emigrant Canal stock is owned by Consolidated District.

[3] Water master's measurements revised by deducting flow of Lone Tree Canal.

[4] Peoples Ditch Company records show that the Settler's Ditch owns 16 1/12 shares; the Corcoran District, 4 1/80 shares in addition to 17.4 per cent of the Settler's Ditch stock, and the Lakeland District, 2 67/120 shares out of a total of 63 13/48 shares of outstanding stock. (No revision made.)

[5] From Consolidated Irrigation District estimates.

[6] The Murphy Slough Canal flows were not separately measured except for portions of each year. The unsegregated remainder has been divided as follows: one-half to Turner-Riverdale Canal, ⅓ to Big and Little Mill Race canals, and ⅙ to Reed Canal. The Murphy Slough Record for 1922 was incomplete—the missing period was assumed equal to the average for the five years 1923, 1925–1928.

[7] Flow records missing or incomplete, values estimated.

[8] Estimated on basis of 2 acre-feet per acre for irrigated pasture and 1 acre-foot per acre for irrigated grain.

[9] Flow for Calamity Canal in 1922 estimated.

[10] Two-thirds grain.

[11] Lakeland Canal jointly owned (50 per cent each) by Corcoran and Lakeland Irrigation districts. Kaweah River water also is received.

[12] Centerville Bottoms with a gross area of 14,623 acres of class 1 and class 2 lands, and various diversion rights for riparian lands, among which are Schultz, Brenner and Clarkes Fork, received water from Kings River for the irrigation of between 10,000 and 20,000 acres of land. Return water, seepage and other inflow are included in the amounts shown, and in 1923 exceeded the consumptive use of these lands.

*Approximately.

For purposes of discussion, the Kings River area as a whole has been divided into smaller local areas and ground water units having similar conditions. These divisions, in the order presented, consist of the Fresno-Consolidated Unit, areas northeast of Fresno Irrigation District, Laguna and Riverdale irrigation districts, areas along north side channels of Kings River, Alta Unit, Foothill Irrigation District and areas served by Kings County canals.

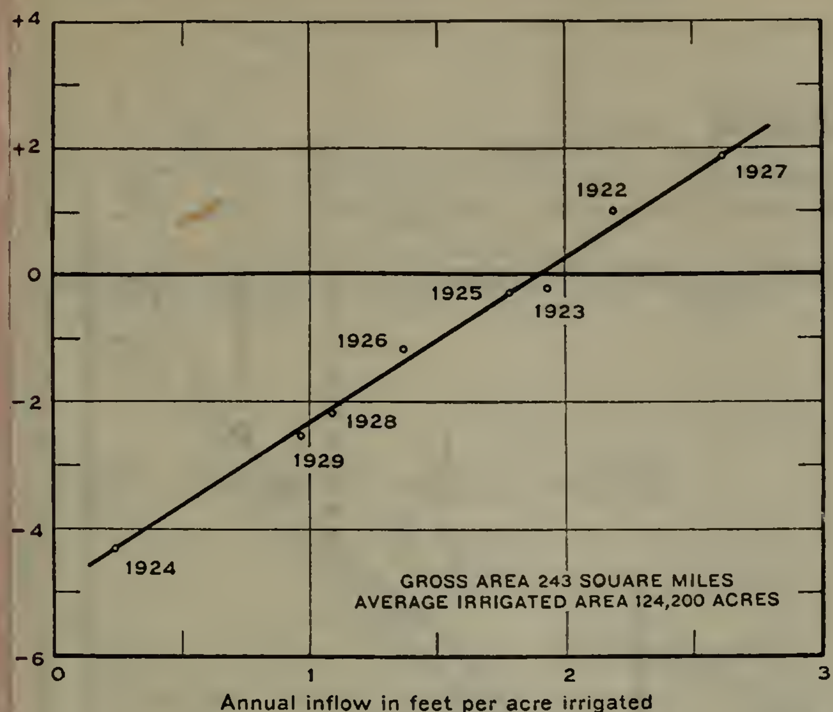
Fresno-Consolidated Unit. This unit includes the total combined area of the two irrigation districts from which its name is derived and a small additional area under pumping development just west of these districts. It extends from the San Joaquin River to the Kings River and has a gross area of 700 square miles, of which 503 square miles, or 321,800 acres, were irrigated in 1929.

The crop surveys in the unit, from which the areas irrigated in each district have been determined, are based on water service areas from which highways, railroads, incorporated and unincorporated towns and main canals have been excluded. The sum of the irrigated areas so determined equals about 80 per cent of the gross irrigable area of this unit.

The Fresno Irrigation District has a gross area of 241,300 acres, of which 192,800 acres were irrigated in 1929. The district has extensive rights of relatively early priority on Kings River and receives a more dependable water supply both in amount and in distribution through the season than other large areas on Kings River. It is generally highly developed, trees and vines constituting the principal plantings. The city of Fresno secures its water supply from ground water within the city area. As a result of irrigation in this area, the ground water has risen from 30 to 60 feet above its elevation prior to the construction of canals.[1] This rise resulted in waterlogging with resulting injury from alkali on much of the lower land in the district. With the increased use of pumping for irrigation in recent years sufficient ground water lowering has occurred so that drainage has been accomplished. In addition to over 30,000 acres which use pumped water exclusively, the larger part of the canal served area also is furnished supplemental service by pumping.

Table 42 shows the records on water supply, irrigation and ground water changes. These show a direct relationship between the water supply per acre and the resulting ground water fluctuation. For the eight-year period, three years show a rise, one year no change and four years a lowering. Plate X shows the lowering from 1921 to 1929 to have varied from zero to ten feet in different parts of the district. Over much of the area the water table has lowered from five to ten feet, with an average of about 5.75 feet. Profile B-B on Plate XX, "Fresno-Consolidated Ground Water Unit," extends southwesterly through Fresno and the wells of the James Irrigation District on McMullin Grade Road to Fresno Slough. Lowering has not been great, except near Fresno. The pumping draft for municipal use in Fresno has resulted in a flattening of the ground water slope immediately beneath the city with a consequent steepening to the eastward. The larger value of diversion per acre irrigated, available to the Fresno

[1] U. S. G. S. Water Supply Paper No. 18, "Irrigation near Fresno, California," 1898.



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR CONSOLIDATED IRRIGATION DISTRICT

FRESNO-CONSOLIDATED GROUND WATER UNIT

For purposes of discussion, the Kings River area as a whole has been divided into smaller local areas and ground water units having similar conditions. These divisions, in the order presented, consist of the Fresno-Consolidated Unit, areas northeast of Fresno Irrigation District, Laguna and Riverdale irrigation districts, areas along north side channels of Kings River, Alta Unit, Foothill Irrigation District and areas served by Kings County canals.

Fresno-Consolidated Unit. This unit includes the total combined area of the two irrigation districts from which its name is derived and a small additional area under pumping development just west of these districts. It extends from the San Joaquin River to the Kings River and has a gross area of 700 square miles, of which 503 square miles, or 321,800 acres, were irrigated in 1929.

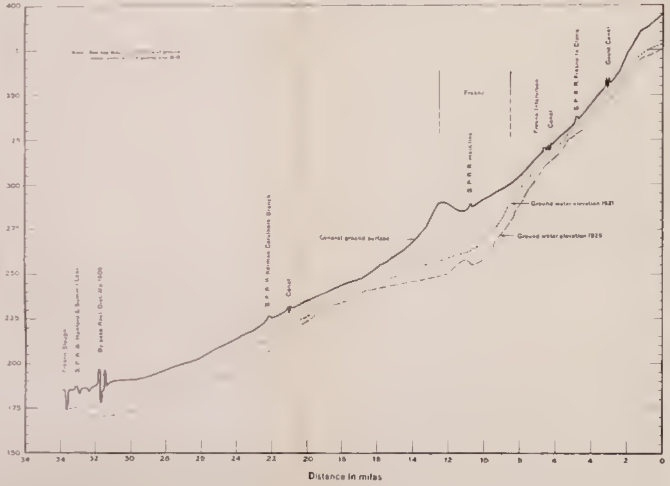
The crop surveys in the unit, from which the areas irrigated in each district have been determined, are based on water service areas from which highways, railroads, incorporated and unincorporated towns and main canals have been excluded. The sum of the irrigated areas so determined equals about 80 per cent of the gross irrigable area of this unit.

The Fresno Irrigation District has a gross area of 241,300 acres, of which 192,800 acres were irrigated in 1929. The district has extensive rights of relatively early priority on Kings River and receives a more dependable water supply both in amount and in distribution through the season than other large areas on Kings River. It is generally highly developed, trees and vines constituting the principal plantings. The city of Fresno secures its water supply from ground water within the city area. As a result of irrigation in this area, the ground water has risen from 30 to 60 feet above its elevation prior to the construction of canals.[1] This rise resulted in waterlogging with resulting injury from alkali on much of the lower land in the district. With the increased use of pumping for irrigation in recent years sufficient ground water lowering has occurred so that drainage has been accomplished. In addition to over 30,000 acres which use pumped water exclusively, the larger part of the canal served area also is furnished supplemental service by pumping.

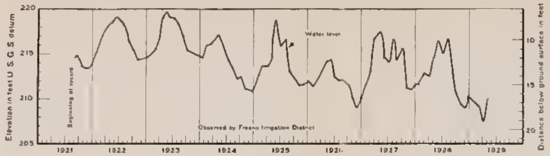
Table 42 shows the records on water supply, irrigation and ground water changes. These show a direct relationship between the water supply per acre and the resulting ground water fluctuation. For the eight-year period, three years show a rise, one year no change and four years a lowering. Plate X shows the lowering from 1921 to 1929 to have varied from zero to ten feet in different parts of the district. Over much of the area the water table has lowered from five to ten feet, with an average of about 5.75 feet. Profile B-B on Plate XX, "Fresno-Consolidated Ground Water Unit," extends southwesterly through Fresno and the wells of the James Irrigation District on McMullin Grade Road to Fresno Slough. Lowering has not been great, except near Fresno. The pumping draft for municipal use in Fresno has resulted in a flattening of the ground water slope immediately beneath the city with a consequent steepening to the eastward. The larger value of diversion per acre irrigated, available to the Fresno

[1] U. S. G. S. Water Supply Paper No. 18, "Irrigation near Fresno, California," 1898.

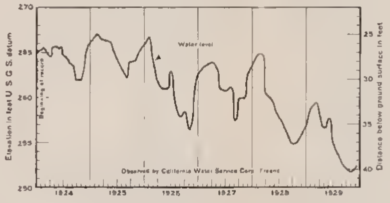
PROFILES ALONG LINE B-B
1921 AND 1929



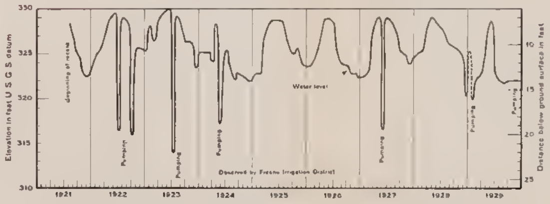
WATER LEVELS IN WELL 14-18-28



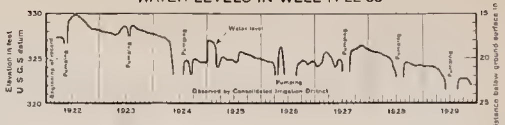
WATER LEVELS IN WELL 14-20-10b



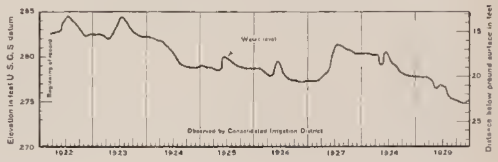
WATER LEVELS IN WELL 14-21-2a



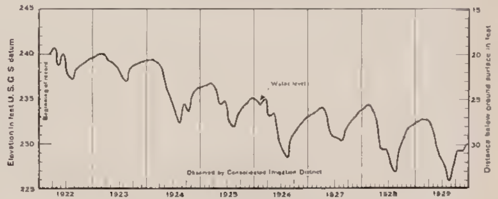
WATER LEVELS IN WELL 14-22-33

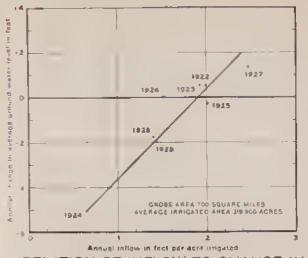


WATER LEVELS IN WELL 16-22-21

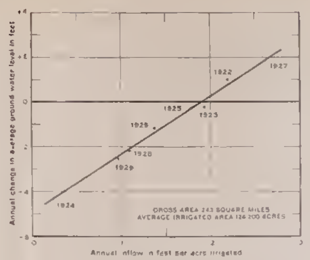


WATER LEVELS IN WELL 15-20-32

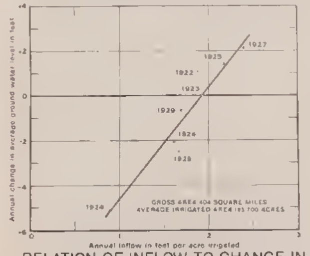




RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR FRESNO-CONSOLIDATED GROUND WATER UNIT



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR CONSOLIDATED IRRIGATION DISTRICT



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR FRESNO IRRIGATION DISTRICT

FRESNO-CONSOLIDATED GROUND WATER UNIT

Irrigation District, is reflected in the smaller relative lowering than that in areas of large development with less adequate canal supplies.

TABLE 42

FRESNO IRRIGATION DISTRICT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Season	Water supply. Diversions into area by canals, in acre-feet	Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
1921–1922	368,000	197,000	1.87	+1.06
1922–1923	378,000	197,000	1.92	0.00
1923–1924	176,000	197,000	.89	−5.12
1924–1925	428,000	197,000	2.17	+1.40
1925–1926	317,000	196,700	1.61	−2.04
1926–1927	466,000	195,000	2.39	+2.14
1927–1928	324,000	193,500	1.67	−2.54
1928–1929	325,000	192,800	1.69	−0.63
Averages, 1921–1929	347,800	195,700	1.78	−0.72

[1] (+) indicates a rise and (—) a fall in ground water level.

On Plate XX the average fluctuations of the ground water are plotted against the canal supplies in acre-feet per acre. A consistent relationship is shown. The line drawn to show the general relationship indicates that a supply of 1.95 acre-feet per acre of cropped area will meet crop needs, supply any excess of ground water outflow over inflow and maintain a stable ground water level. There is some unmeasured but generally small locally tributary run-off from low hill areas above the area, and also probably some ground water outflow to the surrounding lower areas. The cropped area in this district is largely in trees and vines for which the consumptive use is less than that indicated for areas of forage crops.

Well No. 14–18–28 is in the western part of the district southeast of Kerman. The ground water responds to the main irrigation period in the early summer and lowers in the late summer. The total lowering over the whole period has been about five feet. Well No. 14–20–10b is within the City of Fresno. A winter recovery due to lessened municipal draft is shown, the cycle of this well being reversed in time of peak and low point from that in areas having surface irrigation. Lowering since 1925 is shown. Well No. 14–21–2a is east of Fresno near one of the main canals. Quick response to canal flow or pumping is shown with no marked lowering during the period of record.

The Consolidated Irrigation District has a gross area of 149,047 acres of which 129,000 acres were reported as irrigated in 1929. The water rights of the Consolidated District furnish only a limited supply at the medium to low stages of the river but yield a large flow during the short period of high water. Consequently the canal service, while it may be adequate in total amount in years of normal run-off, is not distributed through the season in accordance with crop demands. As a result, practically all canal served lands use supplemental pumping. High ground water has not been as extensive a problem in this district as in some others. There are scattered low areas or pot holes in which water has stood but these represent only a very small percentage of the gross area. With the larger draft on the ground water, during the recent years of subnormal surface supply, practically all of such pot hole areas have become dry. Although the ground water may rise in years of above normal supply, no material problems of drainage are to be anticipated. The lowering from 1921 to 1929 as shown on Plate X varies generally from five to ten feet with small areas of fifteen feet near the Kings River. Table 43 shows the records on water supply, irrigation and ground water fluctuation. A direct relationship between the water supply per acre and the resulting ground water fluctuation is shown. For the eight-year period, a lowering is shown in six years and a rise in two years.

TABLE 43

CONSOLIDATED IRRIGATION DISTRICT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Season	Water supply. Diversions into area by canals, in acre-feet	Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level in feet[1]
1921–1922	269,000	122,700	2.19	+1.0
1922–1923	235,500	121,500	1.94	—0.2
1923–1924	28,000	120,600	0.23	—4.3
1924–1925	218,000	122,000	1.79	—0.3
1925–1926	169,000	123,700	1.37	—1.2
1926–1927	330,000	126,000	2.62	+1.9
1927–1928	138,500	127,600	1.08	—2.2
1928–1929	125,500	129,000	0.97	—2.5
Averages, 1921–1929	189,200	124,200	1.52	—1.0

[1] (+) indicates a rise and (—) a fall in ground water level.

On Plate XX the average fluctuation of the ground water is plotted against the canal supply in acre-feet per acre. The results for the different years fall consistently on a line which indicates that a supply of 1.90 acre-feet per acre of cropped area will meet crop needs, and maintain the ground water without progressive change under existing conditions of ground water inflow and outflow. The cropped area is planted mainly to trees and vines.

Well No. 15–20–32 on Plate XX is located in the west part of the district, north of Caruthers. Lowering occurs during the pumping season with recovery during the winter. This recovery is probably due partly at least to slow movement from higher ground water areas to the east. A general lowering of about ten feet in eight years is shown. Well No. 16–22–21 is located west of Kingsburg. Less marked seasonal fluctuations are shown than for Well No. 15–20–32. A rise occurred in 1927. Some lowering has occurred in other years since 1923. Well No. 14–22–33 is in the upper portion of the district near Sanger. A slow lowering has occurred in the years of smaller canal supply.

The available records on water supply, areas irrigated and ground water fluctuations for the combined area of the Fresno and Consolidated Irrigation Districts are shown in Table 44. The estimated average annual ground water depletion of 71,000 acre-feet for the Fresno-Consolidated Unit for the period 1921–1929 is based upon the difference between the mean net diversions into the area and the product of the average irrigated acreage of 319,900 and a net use of 1.9 acre-feet per acre. The estimated depletion corresponds to a drainage factor of about 20 per cent.

TABLE 44

FRESNO-CONSOLIDATED UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 700 square miles

Season	Water supply. Diversions by canals into area, in acre-feet			Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
	Fresno Irrigation District	Consolidated Irrigation District	Total			
1920–1921	377,000	258,500	635,500	319,100	1.99	----------
1921–1922	368,000	269,000	637,000	319,700	1.99	+0.52
1922–1923	378,000	235,500	613,500	318,500	1.92	+0.55
1923–1924	176,000	28,000	204,000	317,600	0.64	−5.05
1924–1925	428,000	218,000	646,000	319,000	2.02	−0.26
1925–1926	317,000	169,000	486,000	320,400	1.52	+0.03
1926–1927	466,000	330,000	796,000	321,000	2.48	+1.39
1927–1928	324,000	138,500	462,500	321,100	1.44	−1.94
1928–1929	325,000	125,500	450,500	321,800	1.40	−1.73
Averages, 1921–1929	347,800	189,200	537,000	319,900	1.68	−0.81

[1] (+) indicates a rise and (—) a fall in ground water level.

Areas Northeast of Fresno Irrigation District—Northeast of the Fresno Irrigation District are small pump irrigated areas. They are irregularly situated within a strip of territory from one to two miles in width, parallel and adjacent to the Enterprise Canal for a distance of about 20 miles. There are 3300 acres in this area which have no water rights in the Enterprise Canal. These irrigated areas consist of 180 acres of trees of the citrus variety, 40 acres of alfalfa, 1250 acres of vines, 1750 acres of figs and 80 acres of assorted trees of the deciduous variety. The average depth to ground water at the end of 1931 was 38 feet, with extremes of from 12 to 20 feet near the main creek channels and 70 to 80 feet in certain isolated small zones of heavy draft. The water supply for these areas is received from creeks draining the lower foothills of the Sierra Nevada between the Kings and San Joaquin rivers. The principal streams are Dry, Dog and Fancher creeks and Sales Creek, a tributary of Dog Creek. The source of replenishment of ground water supply for the 180-acre citrus development near Round Mountain is Fancher Creek, having a drainage area of 21 square miles, the estimated mean seasonal run-off of which is 1300 acre-feet for the 12-year period, 1917–1929. The sources of replenishment of ground water supplies for the areas of vines, figs, alfalfa and deciduous fruits, totaling 3120 acres, are Dry, Dog and Sales creeks, having a drainage area of 104 square miles, the estimated mean seasonal run-off of which is 6300 acre-feet for the 12-year period.

Laguna and Riverdale Irrigation Districts—These two districts cover lands on the north side of Kings River between the river and Murphy Slough. The total area in the Laguna District is 34,858 acres of which 22,500 acres were irrigated in 1929. In the Riverdale District the gross area is 15,830 acres with 8640 acres irrigated in 1929. Pumping from wells in these districts has been increased in recent years. Such pumping was not practiced extensively as early in their development as in the adjacent larger districts. The rights of these districts include some low water flow with the larger part of the supply secured at higher stages. Ground water has been relatively high under much of the area but appears to be under control with the present amount of pumping.

Areas Along North Side Channels of Kings River—There are several separate irrigation systems located along the channels of Kings River leading to the north toward the San Joaquin River. They are listed in Table 45, together with their gross areas and areas irrigated in 1929.

TABLE 45

IRRIGATION SYSTEMS ALONG NORTH SIDE OF LOWER KINGS RIVER

Name of system	Gross area, in acres	Area irrigated in 1929, in acres
Cuthbert Burrel	11,518	3,740
Stinson Irrigation District	11,750	5,984
Crescent Irrigation District	13,150	2,894
James Irrigation District	26,266	11,640
Tranquillity Irrigation District	10,750	6,700
Residual Murphy Slough Group	10,700	6,780
Totals	84,134	37,738

These systems divert directly from Kings River when water is available. The rights to Kings River flow are mainly applicable at the higher stages and yield a variable supply. Supplemental pumping is used at times when river water is not available. Some wells operated by individual landowners are used, but generally such supplemental pumping is by means of batteries of plants pumping from wells into the canal systems. The James and Tranquillity Districts have some rights to pump San Joaquin River water from Fresno Slough. The James District operates both deeper wells within the district and shallow wells in the general area of undeveloped land between Fresno Slough and the Fresno Irrigation District. The estimated pumping draft from these shallow wells is 24,000 acre-feet for 1929 and an average annual of 17,000 acre-feet during the period 1921–29. There is an area of about 180,000 acres of generally poor land between the Fresno and Consolidated Irrigation Districts on the east, and the better lower lands along the lower channels. There is little local development in this area. Ground water was formerly close to the surface and now although lowered about eight feet in the past eight years is still at less depth than in many developed areas.

Alta Unit. This unit consists principally of lands in the Alta Irrigation District on the south side of Kings River and contains 122,000 acres, of which 68,450 acres were irrigated in 1929. It covers the upper canal served area on the south side of Kings River. Its rights in Kings River furnish the larger part of the water supply within a rather short period during high water. While only a small area depends entirely on pumping, nearly all the irrigated land secures supplemental irrigation from wells. High ground water has damaged some of the lower portions of the district. Such lands are used mainly for pasture. The general ground water lowering during recent years of less than average water supply has removed any problems of drainage in the cropped areas. Ground water lowering from 1921 to 1929 is shown on Plate X. This has varied in the different parts of the district depending on relative supply and draft. Lowering of 25 to 35 feet has occurred along the upper portion of the district away from Kings River. In the southern part of the district, used mainly for pasturage with little canal service or pumping, the lowering has varied from nothing to five feet. Lowering in the central portion has varied from five to fifteen feet.

Table 46 shows the records of water supply, area irrigated and ground water fluctuations for the area in the Alta Unit. The area irrigated represents the cropped area, exclusive of the pasture lands in the southern part of the district, to which some water for stock purposes and some flooding is delivered. In making the crop survey of 1929 from which the irrigated area for this unit has been determined, all highways, railroads, incorporated and unincorporated towns, main canals, main laterals and sublaterals and building and uncropped areas of more than one acre were excluded. County and private roads, private ditches and building areas and yards of less than one acre situated within the cropped areas were included.

TABLE 46

ALTA UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 191 square miles

Season	Water supply. Canal diversions, in acre-feet	Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
1921-1922	167,000	80,200	2.08	+0.48
1922-1923	145,000	81,600	1.78	+1.28
1923-1924	33,000	83,300	0.40	—8.44
1924-1925	156,000	81,600	1.91	+1.44
1925-1926	122,000	80,000	1.53	—2.95
1926-1927	244,000	81,600	2.99	+6.14
1927-1928	119,000	75,000	1.59	—4.29
1928-1929	85,500	68,450	1.25	—4.88
Averages, 1921-1929	133,900	79,000	1.69	—1.40

[1] (+) indicates a rise and (—) a fall in ground water level.

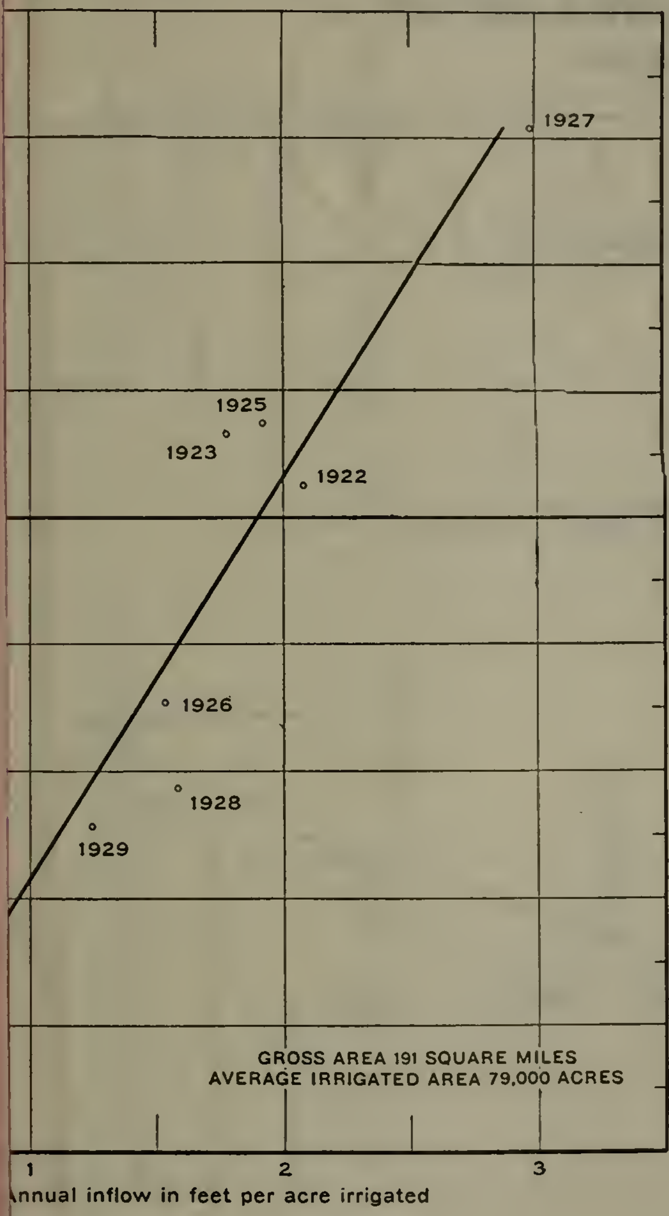
Table 46 shows that, for four years of the period of record, the supply has exceeded the use and the ground water has risen. In the other four years the supply was less than the net use and ground water storage was drawn upon with a consequent lowering. In 1924 with practically no canal supply, an average lowering of over eight feet occurred. In 1927 with a supply of about three acre-feet per acre irrigated there was an average rise of six feet.

The average annual ground water fluctuations and inflow per acre are plotted for each of the eight years of record on Plate XXI, "Alta Ground Water Unit." A fairly consistent relationship is shown. The line drawn to represent the relationship of supply and fluctuations indicates that a supply of about 1.90 acre-feet per acre will meet crop use and maintain present ground water elevations. This rate of supply would also meet any excess of ground water outflow over inflow and includes a supply for use that may occur on pasture areas not included in the crop areas. This rate of use is smaller than that indicated for some other areas. This difference is considered to be due to the fact that crops in the Alta area are very largely deciduous fruits and grapes having a smaller consumptive use than forage crops. The estimated average annual depletion of 20,000 acre-feet for the Alta Unit, for the period 1921–1929, is approximately the difference between the mean canal diversions and the indicated net supply required for the average area of 79,000 acres. The indicated average drainage factor for this unit is about 12 per cent.

Profile CC on Plate XXI shows the slope of the water table and the lowering that has occurred. This profile extends southwesterly from the Alta Canal across the central portion of the Alta District to the southwestern corner of the district. It further extends to the southwest across the central portion of the South Kings area. The profile illustrates the more rapid lowering that has occurred in the upper part of the Alta District where the pumping draft is heavy. There is less cropped area in the lower part of the district so that the lowering has been small due to the lighter pumping draft. In the South Kings area, records are available since 1925 only. The ground water is fairly close to the ground surface and has shown little change.

Hydrographs of four typical wells in the Alta District also are shown on Plate XXI. Well No. 15–23–13C is in the upper portion of the district about three miles from Kings River. This well shows a rapid rise, in response to the flow of water in the Alta canal system, in the early summer with a similar rapid lowering after canal service ends. While the lowering for the very dry year of 1924 was largely recovered in 1927, the total lowering over the eight years shown has exceeded 25 feet. Well No. 17–23–15 is located in the lower portion of the district where the land is used mainly for pasture. The canal service and pumping in this area are limited. In years of larger canal supply, delivery into this area is also larger. These conditions are reflected in the fluctuations of this well. Little total lowering has occurred in the eight year period. In 1924 the ground water dropped to about ten feet below the ground surface to the probable limit of use by vegetation through subirrigation, but did not continue to lower materially in 1925 or 1926. The larger supply in 1927 caused a rise to within four feet of the ground surface. In 1929 it dropped back again to the capillary limit of subirrigation. Wells No. 16–24–30a, b, and c are located two miles southwest of Dinuba in the lower portion of the cropped area of the district and about five miles from Kings River. They show a less marked response to canal supply than wells in the upper part of the district. Their fluctuations are intermediate between those of wells 17–23–15 and 15–23–13c. Well No. 16–25–30a is in the cropped area southeast of Dinuba. Water rose to within about five feet of the ground surface in 1922, but remained over ten feet below since 1924. The recovery in 1927 was lost in 1928 and 1929 and the ground water shows a total lowering of about 20 feet for the full period.

ON OF INFLOW TO CHANGE
EVEL OF GROUND WATER

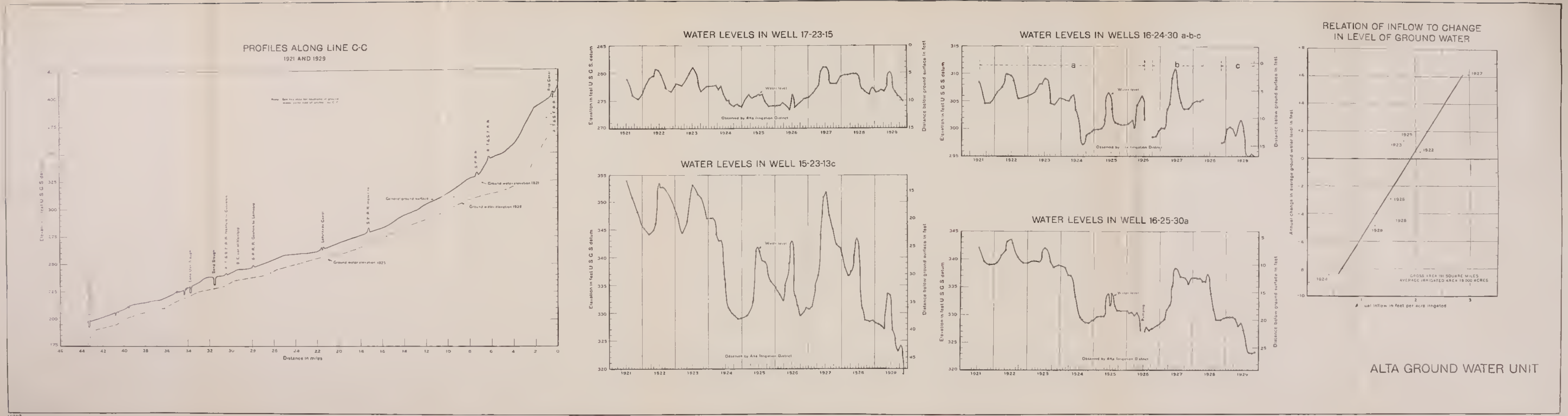


ALTA GROUND WATER UNIT

indicates that a supply of about 1.90 acre-feet per acre will meet crop use and maintain present ground water elevations. This rate of supply would also meet any excess of ground water outflow over inflow and includes a supply for use that may occur on pasture areas not included in the crop areas. This rate of use is smaller than that indicated for some other areas. This difference is considered to be due to the fact that crops in the Alta area are very largely deciduous fruits and grapes having a smaller consumptive use than forage crops. The estimated average annual depletion of 20,000 acre-feet for the Alta Unit, for the period 1921–1929, is approximately the difference between the mean canal diversions and the indicated net supply required for the average area of 79,000 acres. The indicated average drainage factor for this unit is about 12 per cent.

Profile CC on Plate XXI shows the slope of the water table and the lowering that has occurred. This profile extends southwesterly from the Alta Canal across the central portion of the Alta District to the southwestern corner of the district. It further extends to the southwest across the central portion of the South Kings area. The profile illustrates the more rapid lowering that has occurred in the upper part of the Alta District where the pumping draft is heavy. There is less cropped area in the lower part of the district so that the lowering has been small due to the lighter pumping draft. In the South Kings area, records are available since 1925 only. The ground water is fairly close to the ground surface and has shown little change.

Hydrographs of four typical wells in the Alta District also are shown on Plate XXI. Well No. 15–23–13C is in the upper portion of the district about three miles from Kings River. This well shows a rapid rise, in response to the flow of water in the Alta canal system, in the early summer with a similar rapid lowering after canal service ends. While the lowering for the very dry year of 1924 was largely recovered in 1927, the total lowering over the eight years shown has exceeded 25 feet. Well No. 17–23–15 is located in the lower portion of the district where the land is used mainly for pasture. The canal service and pumping in this area are limited. In years of larger canal supply, delivery into this area is also larger. These conditions are reflected in the fluctuations of this well. Little total lowering has occurred in the eight year period. In 1924 the ground water dropped to about ten feet below the ground surface to the probable limit of use by vegetation through subirrigation, but did not continue to lower materially in 1925 or 1926. The larger supply in 1927 caused a rise to within four feet of the ground surface. In 1929 it dropped back again to the capillary limit of subirrigation. Wells No. 16–24–30a, b, and c are located two miles southwest of Dinuba in the lower portion of the cropped area of the district and about five miles from Kings River. They show a less marked response to canal supply than wells in the upper part of the district. Their fluctuations are intermediate between those of wells 17–23–15 and 15–23–13c. Well No. 16–25–30a is in the cropped area southeast of Dinuba. Water rose to within about five feet of the ground surface in 1922, but remained over ten feet below since 1924. The recovery in 1927 was lost in 1928 and 1929 and the ground water shows a total lowering of about 20 feet for the full period.


PROFILES ALONG LINE C-C
1921 AND 1929
Distance in miles
Ground water elevation 1921
Ground water elevation 1929
General ground surface
WATER LEVELS IN WELL 17-23-15
Observed by Alta Irrigation District
WATER LEVELS IN WELL 15-23-13c
Observed by Alta Irrigation District
WATER LEVELS IN WELLS 16-24-30 a-b-c
WATER LEVELS IN WELL 16-25-30a
Observed by Alta Irrigation District
Elevation in feet U S G S datum
Distance below ground surface in feet
Water level
RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER
GROSS AREA 191 SQUARE MILES
AVERAGE IRRIGATED AREA 18,000 ACRES
ALTA GROUND WATER UNIT

40997

Foothill Irrigation District. This district extends along the foothills south from Kings River and above the Alta Irrigation District. It has no present canal system or supply. The gross area is 50,687 acres of which a net area of 11,000 acres was irrigated by pumping in 1929. The area is adapted to citrus culture and present crops are largely of this character. The ground water records are very meager for this area. Material lowering has occurred. It is generally recognized that this area is one of practically zero ground water replenishment. The depth to the underlying granite is less than in the valley areas and the available ground water accumulation is correspondingly small. The Foothill District was organized as a means of endeavoring to secure additional water supplies but to date has not succeeded.

Areas Served by Kings County Canals—The area considered herein embraces lands served by the systems of the Peoples, Last Chance and Lemoore canals which serve adjacent areas on the south side of Kings River in Kings County. The development is a relatively old one. The water supply obtained from Kings River has been sufficient to cause high ground water under much of the area. Such lands are used largely for pasture. In recent years some supplemental pumping has been installed but the extent of the use of the ground water is much less than in the upper Kings River area. Drainage would be beneficial to much of this land under the ground water conditions of years of normal run-off. The gross area, area of Classes 1 and 2 lands and the net area irrigated in 1929 for each of these systems is set forth in Table 47.

TABLE 47

CANAL SYSTEMS IN KINGS COUNTY

Name of system	Gross area, in acres	Area of classes 1 and 2 land in acres	Irrigated area in 1929, in acres
Peoples	72,152	51,198	23,400
Last Chance	33,407	31,279	19,556
Lemoore	53,100	47,071	14,574
Totals	158,659	129,548	57,530

The Lakeside Ditch supplied from the Kaweah River serves lands in the eastern part of this area and has generally similar conditions.

Tulare Lake Area.

This area, as the term is here used, covers the general area of the Tulare Lake Basin Water Storage District and the adjacent Corcoran and Lakeland irrigation districts. These districts have water rights on Kings River, mainly at higher stages of flow. Tulare Lake formerly occupied much of this area in years of excessive run-off. Greater use of water for irrigation coupled with a series of years of sub-normal run-off have resulted in only limited inflow reaching the lake in recent years. The larger part of the bed of Tulare Lake has been reclaimed by levees limiting the overflow area. Due to the uncertainty of water supply and menace of overflow, the crops grown in the lake bed are limited largely to grain. However, there is more diversity of crops on the higher lands. Ground water conditions vary in this area. Artesian wells formerly were obtainable. Water is obtained mainly from deeper strata and many wells are 1500 to 2000 feet deep. The water bearing materials are generally fine. The formation is considered relatively nonabsorptive and a definite natural barrier along the eastern rim seems to resist ground water movement into the area from the east. The depth to ground water in wells in June of 1929 was about 100 feet as compared with that of 30 feet in the area just east of Corcoran on the outer Tule Delta. Data on a few scattered wells indicate an average lowering of ground water levels of about 40 feet between 1926 and 1929. In some areas irrigation has resulted in building up an artificial, shallow ground water supply which is used to some extent with the deeper water.

Hydrographic Divisions 5 and 5B.

These divisions cover the west side lands from Mendota south. There are no canal systems as there are no available local surface water supplies. The lower, canal served lands along the Kings River channels, are included in the Kings River areas. Some pumping from local ground water has been developed. Deep wells are required. The upper ground water is generally of unsatisfactory quality and wells are perforated only in the lower strata. The total area irrigated in 1929 was about 50,000 acres, practically all of which was within the lower portion of Division 5.

Madera Unit.

This unit has been included in the upper San Joaquin Valley because it is an area in which present use of ground water supplies exceeds the replenishment from local sources, and the natural and most practicable source of supplemental supply required to meet the deficiency between average use and availability of ground water supplies is the San Joaquin River which is also the proposed source of supplemental supply for the remaining easterly portion of the upper San Joaquin Valley. Bounded on the north by the Chowchilla River, on the south by the San Joaquin River and on the east by the line of the Santa Fe Railroad, it extends westward an average distance of fifteen miles to the area served by the present east side canals diverting from San Joaquin River.

The Madera area has had a lengthy history in its efforts to secure canal irrigation. The present Madera Irrigation District was organized with an area of 352,000 acres in 1920. Efforts to work out an adjustment of rights on San Joaquin River resulted in the organization of the San Joaquin River Water Storage District in 1923. That district had a total area of about 550,000 acres including about 184,000 acres in the Madera District as well as the other crop lands served from the San Joaquin River. As efforts to reach a basis on which the storage district could proceed were not successful, it was dissolved in 1929 and the Madera District resumed its efforts to secure a separate supply. The area in the district was reduced by the exclusion of poorer lands to a present area of about 182,000 acres. The district plans include storage on the San Joaquin River at Friant and canals extending as far north as Chowchilla River. Although the area has not as yet succeeded in securing a supply from the San Joaquin River, irrigation has proceeded through the use of Fresno River water and wells. Both Fresno and Chowchilla rivers cross this area and contribute to its ground water. The Madera Canal and Irrigation Company serves a variable area averaging about 10,000 acres near Madera by diversion of direct flow from Fresno River. Both of these streams drain lower portions of the Sierra Nevada and have less regular and dependable run-offs than streams draining higher areas.

Ground water is extensively used, a total of 81,000 acres being wholly or partially irrigated, in 1929, from this source. The principal areas now developed are located from Madera south to the San Joaquin River and in the vicinity of Chowchilla. Ground water contours are shown on Plate VIII. These indicate the effect of replenishment from Fresno and Chowchilla rivers and of the concentration of pumping south of Madera and southwest of Chowchilla. Plate X shows the lowering that has occurred from 1921 to 1929. This has been generally five to ten feet near Fresno River and fifteen to twenty feet south of Madera. Lowering up to 25 feet has occurred in the main pumping areas near Chowchilla. General lowering of ten to twenty feet has occurred in the area between Madera and Chowchilla. Present depths to water as shown on Plate IX vary from fifty to seventy feet in the southeastern part of the area to five to twenty feet in the lower west side areas. Near Chowchilla general depths are thirty to fifty feet. Plates VIII and X do not indicate any material effect on the ground water of this area due to such percolation as may occur from San Joaquin River. The river has a net gain in the section bordering the Madera Unit. Any percolation from the channel affects only a narrow strip adjacent thereto.

Table 48 shows the available data on water supply, areas irrigated and ground water fluctuations for the period, 1921 to 1929. Wells in

TABLE 48

MADERA AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 343 square miles

Season	Water supply				Area irrigated, in acres[2]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[3]
	Run-off of Fresno River near Knowles, in acre-feet	Fresno Lumber Company flume contribution, in acre-feet	Run-off of Chowchilla River at Buchanan, in acre-feet[1]	Total inflow, in acre-feet			
1921–1922	93,000	4,100	108,000	205,100	60,000	3.42	+0.55
1922–1923	82,300	4,100	68,400	154,800	62,100	2.49	—0.17
1923–1924	13,200	3,200	7,600	24,000	64,300	0.37	—2.74
1924–1925	45,600	4,000	85,000	134,600	66,400	2.03	—1.83
1925–1926	31,000	4,000	31,700	66,700	68,500	0.97	—1.82
1926–1927	69,800	4,000	69,800	143,600	72,700	1.98	—0.55
1927–1928	44,200	4,100	52,000	100,300	77,000	1.30	—1.34
1928–1929	21,200	4,100	36,800	62,100	81,000	0.77	—3.37
Averages, 1921–1929	50,040	3,950	57,410	111,400	69,000	1.61	—1.41

[1] Stream flow records for seasons 1921–1922 and 1922–1923, other seasons estimated from indices of seasonal wetness, Division K.
[2] Area for 1929 from crop survey; other years estimated.
[3] (+) indicates a rise and (—) a fall in ground water.

this area have been read only in the spring and fall. The figure for the area irrigated in 1929 is based on an actual survey. Those for preceding years are estimated from the best data available as there are no actual records for earlier years. In making the 1929 crop survey, highways, railroads, incorporated and unincorporated towns and building and minor uncropped areas of more than five acres were excluded. County and private roads, canals, ditches and buildings and uncropped areas of less than five acres, situated within the cropped areas, were included.

The records for this area do not permit of a direct comparison of supply and use, as part of the tributary run-off passes across the area without diversion or absorption. The results shown in the table indicate that an inflow of about 2.5 acre-feet per acre irrigated is needed to furnish a sufficient supply to this area for crop use and outflow. The proportion of the run-off retained within the area varies with the character of its occurrence as well as with its amount. The estimated average annual depletion of 61,000 acre-feet is based upon the difference between an indicated average net use requirement of 2.5 acre-feet per acre for 69,000 acres and the mean seasonal inflow of 111,400 acre-feet. The indicated average drainage factor for this unit is about 20 per cent.

Profile A-A on Plate XXII, "Madera Ground Water Unit," extends west from a point near the crossing of the Santa Fe Railroad and the Fresno River to a point two miles north and eight miles west of Madera and thence in a direction somewhat north of west to Chowchilla River. A lowering of about twenty feet is shown on this line in the westerly part of the unit.

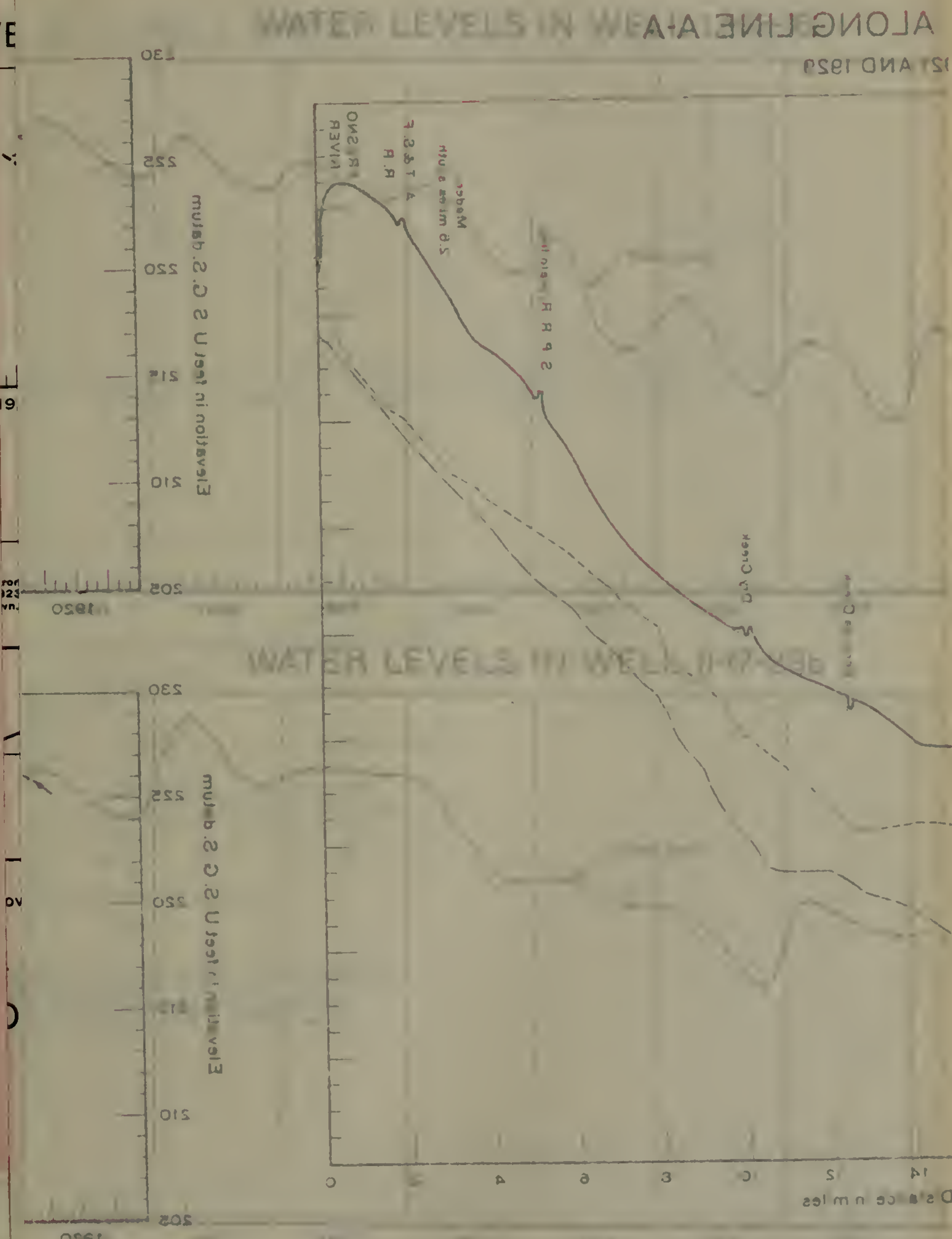
Hydrographs of three wells are shown on Plate XXII. Well 12–18–16 shows fairly uniform lowering from October, 1921, to October, 1929, with a total of about eighteen feet. Well 11–17–33b shows lowering from March, 1922, with some recovery in 1927 and about the same total lowering. Well 10–16–4 shows lowering from October, 1920, to October, 1929, with some recovery in 1922, 1923 and 1927 and a total lowering of about twelve feet.

Net Use in Ground Water Units of Upper San Joaquin Valley.

The foregoing analyses of net use in the several ground water units of the upper San Joaquin Valley indicate that where the use of water is predominately that for irrigation of crops and there is little outflow, the annual net use closely approximates 2.0 acre-feet per acre of irrigated crops. The greater net use indicated in certain of the areas such as the Kaweah, Tule-Deer Creek and Madera units is undoubtedly due to use of water in large areas of natural vegetation (trees, grass lands, etc.), a material amount of unmeasurable outflow or other irrecoverable losses, the combined amount of which is substantially greater in these units in relation to cropped area and crop use than in the units more intensely developed to crop production.

LOWER SAN JOAQUIN VALLEY

Irrigation development in the lower San Joaquin Valley divides itself naturally into three parts on the basis of sources of water supply. These sources of supply are the main San Joaquin River, the east side tributaries of the San Joaquin River and the channels of the San


ALONG LINE A-A
Dry Creek
0
2
4
6
8
10
12
14
Distance in miles

this area have been read only in the spring and fall. The figure for the area irrigated in 1929 is based on an actual survey. Those for preceding years are estimated from the best data available as there are no actual records for earlier years. In making the 1929 crop survey, highways, railroads, incorporated and unincorporated towns and building and minor uncropped areas of more than five acres were excluded. County and private roads, canals, ditches and buildings and uncropped areas of less than five acres, situated within the cropped areas, were included.

The records for this area do not permit of a direct comparison of supply and use, as part of the tributary run-off passes across the area without diversion or absorption. The results shown in the table indicate that an inflow of about 2.5 acre-feet per acre irrigated is needed to furnish a sufficient supply to this area for crop use and outflow. The proportion of the run-off retained within the area varies with the character of its occurrence as well as with its amount. The estimated average annual depletion of 61,000 acre-feet is based upon the difference between an indicated average net use requirement of 2.5 acre-feet per acre for 69,000 acres and the mean seasonal inflow of 111,400 acre-feet. The indicated average drainage factor for this unit is about 20 per cent.

Profile A-A on Plate XXII, "Madera Ground Water Unit," extends west from a point near the crossing of the Santa Fe Railroad and the Fresno River to a point two miles north and eight miles west of Madera and thence in a direction somewhat north of west to Chowchilla River. A lowering of about twenty feet is shown on this line in the westerly part of the unit.

Hydrographs of three wells are shown on Plate XXII. Well 12–18–16 shows fairly uniform lowering from October, 1921, to October, 1929, with a total of about eighteen feet. Well 11–17–33b shows lowering from March, 1922, with some recovery in 1927 and about the same total lowering. Well 10–16–4 shows lowering from October, 1920, to October, 1929, with some recovery in 1922, 1923 and 1927 and a total lowering of about twelve feet.

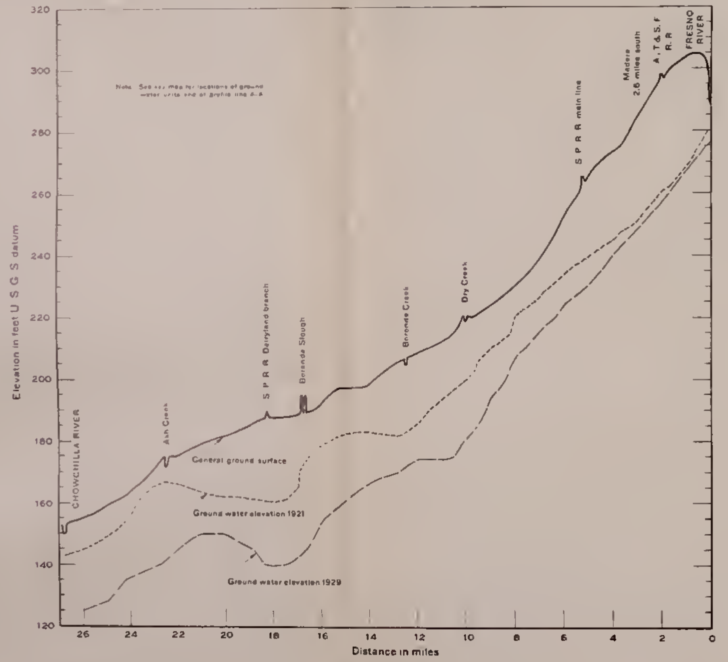
Net Use in Ground Water Units of Upper San Joaquin Valley.

The foregoing analyses of net use in the several ground water units of the upper San Joaquin Valley indicate that where the use of water is predominately that for irrigation of crops and there is little outflow, the annual net use closely approximates 2.0 acre-feet per acre of irrigated crops. The greater net use indicated in certain of the areas such as the Kaweah, Tule-Deer Creek and Madera units is undoubtedly due to use of water in large areas of natural vegetation (trees, grass lands, etc.), a material amount of unmeasurable outflow or other irrecoverable losses, the combined amount of which is substantially greater in these units in relation to cropped area and crop use than in the units more intensely developed to crop production.

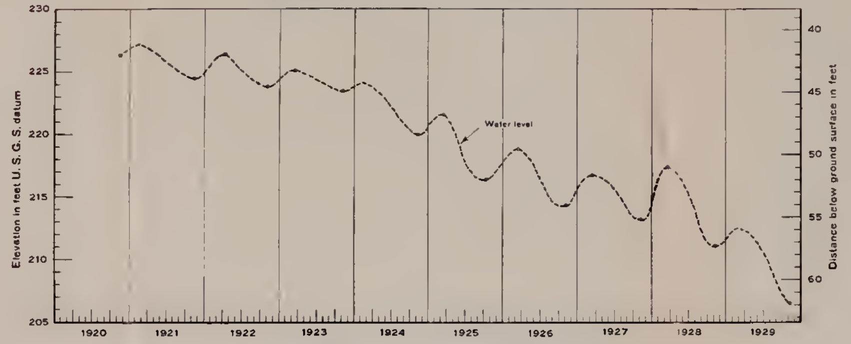
LOWER SAN JOAQUIN VALLEY

Irrigation development in the lower San Joaquin Valley divides itself naturally into three parts on the basis of sources of water supply. These sources of supply are the main San Joaquin River, the east side tributaries of the San Joaquin River and the channels of the San

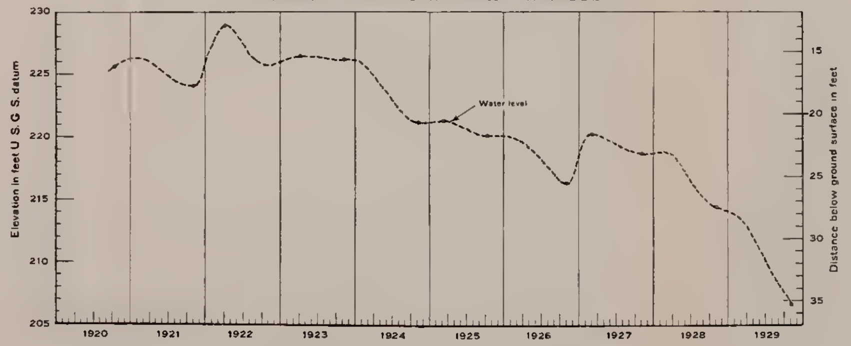
PROFILES ALONG LINE A-A
1921 AND 1929



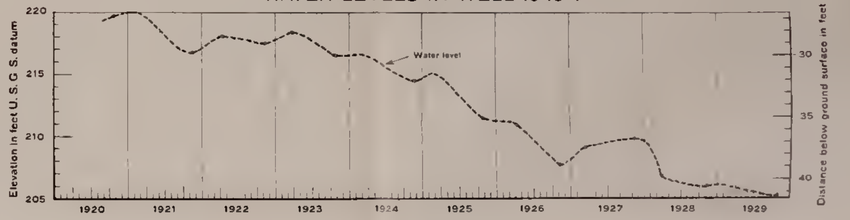
WATER LEVELS IN WELL 12-18-16

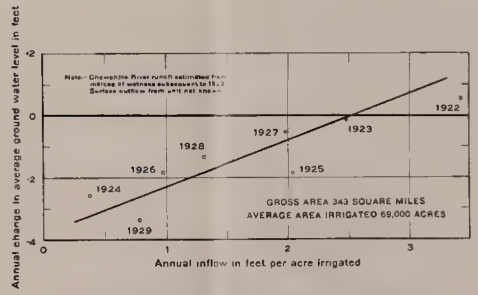


WATER LEVELS IN WELL 11-17-33b



WATER LEVELS IN WELL 10-16-4





RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER

MADERA GROUND WATER UNIT

Joaquin Delta. As the run-off of west side tributaries is practically negligible in amount, the main San Joaquin River supplies all west side areas now developed from surface waters as well as some lower east side areas above the mouth of Merced River. The remaining east side areas are served from the east side tributaries.

The adequate water supply of the lower San Joaquin Valley has resulted in a different type of development from that used in the upper valley. Pumping from wells for irrigation is practiced to only a limited extent by individuals. Irrigation is accomplished by means of canal systems. Sufficient storage has been constructed on the three principal east side streams to yield practically a full seasonal surface supply for the areas now dependent thereon. Adequate supplies also are secured by the lower west side systems pumping from the San Joaquin River due to the availability of return flows from higher irrigated areas. The larger part of the development is now under the irrigation district form of organization. In order to show the location and extent of present irrigation development in the lower San Joaquin Valley, two plates have been prepared. Plate XXIII, "Lands With Irrigation Service from San Joaquin River Above Mouth of Merced River," shows canal systems, "Crop Lands," "Grass Lands" and lands considered riparian for the area specified. Plate XXIV, "Lands With Irrigation Service in San Joaquin Valley North of Merced," shows the boundaries of organized districts and canal systems for the area specified.

Lands with Irrigation Service from San Joaquin River Above Mouth of Merced River.

The areas described under this general heading cover the lands served by diversions from the San Joaquin River above the mouth of the Merced River. They include some land below the Merced River on the west side which is served from higher diversions. The larger part of existing development is served by canals controlled by Miller & Lux, Incorporated. These include canals serving the lands of that company as well as canals serving lands of mixed ownership.

Conditions regarding diversion and use on the San Joaquin River are quite complex. Uses under riparian and appropriative rights are intermingled; two classes of agricultural practice, crop and grass land, occur. There are differences in claims regarding title to use. Many efforts to work out agreements regarding present rights and efforts to increase the use of this stream have been made, and much has been accomplished.

Extensive storage for power has been built on the upper drainage area. The Southern California Edison Company in connection with the Big Creek development has storage capacities of 64,400 acre-feet above the Florence Tunnel, 88,800 acre-feet at Huntington Lake and 135,300 acre-feet at Shaver Lake. The San Joaquin Light and Power Corporation has storage of 45,000 acre-feet capacity at Crane Valley on the North Fork. Storage sites are available below present power plants for use for irrigation. The conditions of operation of the power storage are covered by contracts between the power companies and lower riparian owners.

Pumping plants used for generally small areas along the river serve a total of about 5000 acres from Friant to the Gravelly Ford diversion. The highest existing canal is the Gravelly Ford. This canal, together with the Aliso and the Brown and Lone Willow sloughs, from which the Columbia and Chowchilla canals are supplied, serve the lands on the north side of the river having diversions above Mendota. These diversions serve both crop and grass lands.

The San Joaquin River turns northward at Mendota, where Fresno Slough enters the San Joaquin River from the south. In all but dry years Kings River water reaches the lower portion of Fresno Slough. In high flows the San Joaquin River overflows through Lone Tree Slough and other channels across the Herminghaus lands to Fresno Slough. At lower stages San Joaquin River water is backed up Fresno Slough by the Mendota Weir. Pumping diversions by the James and Tranquillity irrigation districts, which comprise part of the area in the James Ranch, are permitted when the flow of the San Joaquin River at Friant exceeds 1360 second-feet.

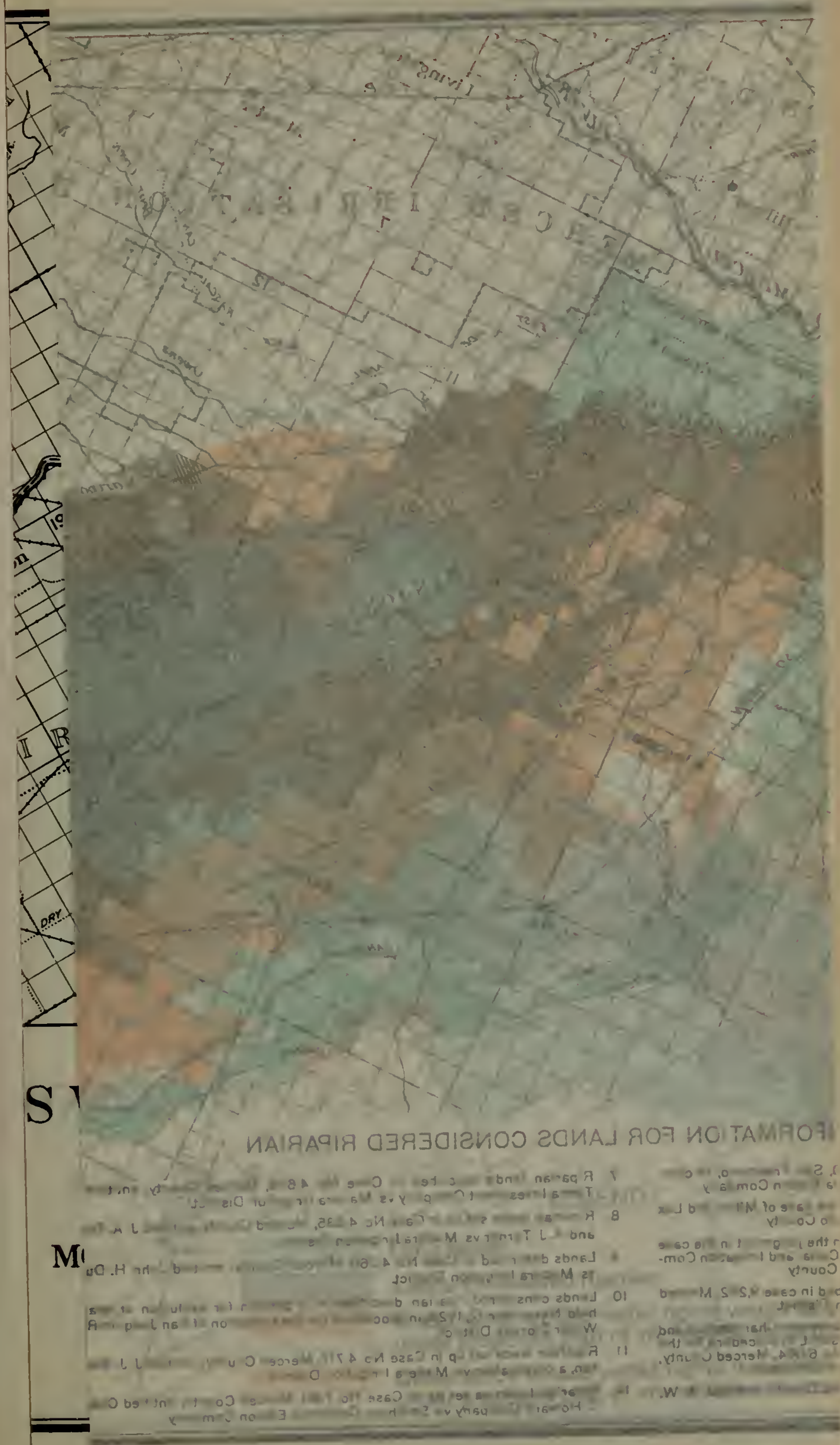
Several large canal diversions head at the Mendota Weir. The largest of these is the San Joaquin and Kings River Canal, including the Main and Outside canals, serving lands on the west side of the San Joaquin River. This system operates as a public utility and serves both crop and grass lands in an area extending northward to the area served by the pumping system of the Patterson Water Company,

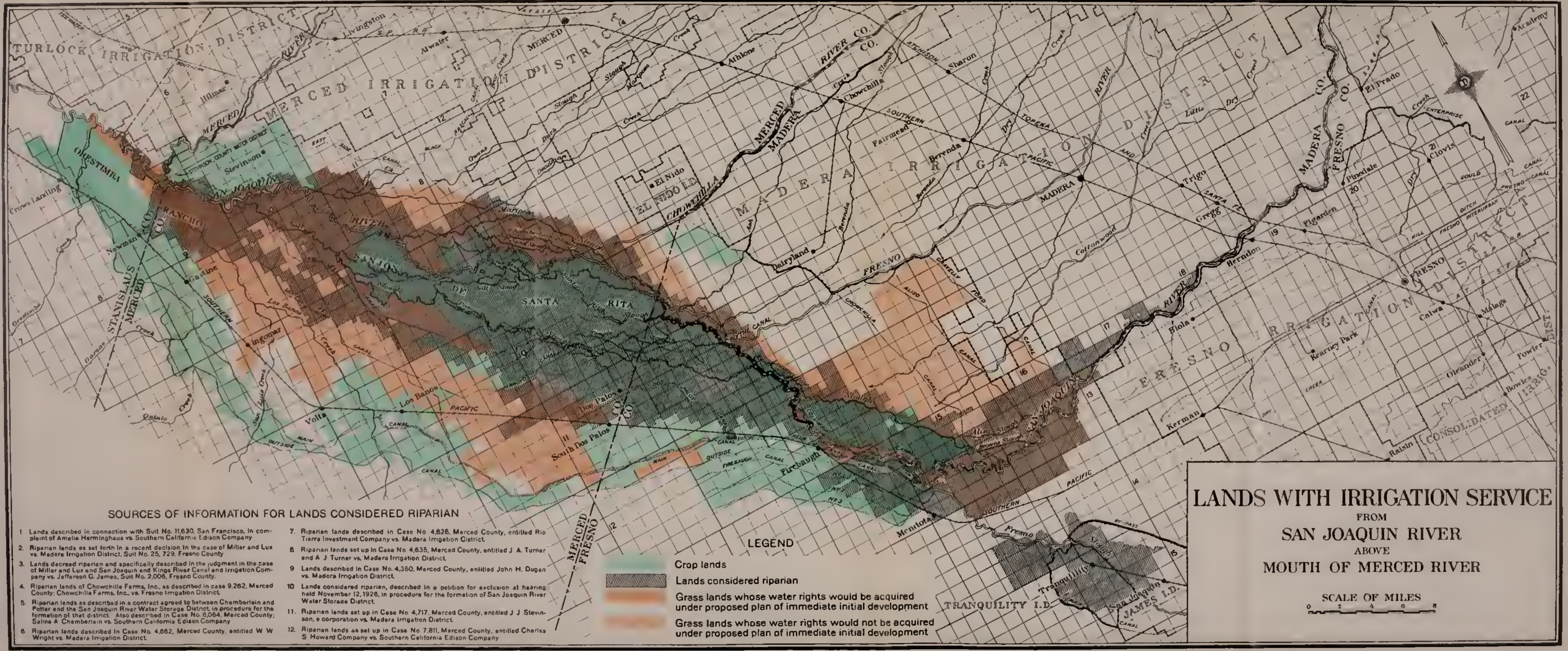
TABLE 49

DIVERSION CAPACITIES OF CANALS AND AREAS OF IRRIGATION SERVICE FROM SAN JOAQUIN RIVER, ABOVE MOUTH OF MERCED RIVER

Diversion	Capacity, in second-feet		Irrigated areas, in acres			
			Crop land			Grass land
	Maximum	Operating	Now irrigated	Probable additional irrigation	Total	
Private pumping plants	138	138	4,500	500	5,000	
Gravelly Ford	900	600				14,000
Aliso	700	500				22,000
Browns Slough[1]	300	200				
Lone Willow Slough	500	400				23,000
Columbia[2]		250	16,000		16,000	
Chowchilla[3]		120	3,000	7,000	10,000	(7)
Fresno Slough Diversion	140	140	10,000	4,000	14,000	
Firebaugh	300	300	24,000		24,000	
San Joaquin and Kings River (outside) (3, 5)	600	500	32,500		32,500	
San Joaquin and Kings River (main) (3, 6)	1,300	1,000	81,000		81,000	37,500
San Luis Canal Company Helm Canal (4, 6)	700	600	40,500		40,500	58,500
Helm Ditch[3]	35	35	1,500		1,500	
Blythe		450				14,000
Temple Slough[4]		500	47,500		47,500	
Pick Anderson Slough[4]	1,000	Varies				
San Luis Island[4]		200				
East Side	500	250	10,000	10,000	20,000	
Herminghaus						16,000
Unregulated diversion and overflow						47,000
State Game Farm	14	14	3,000		3,000	
Totals			273,500	21,500	295,000	232,000

[1] Diverts into Lone Willow Slough—areas shown under Lone Willow Slough.
[2] Diverts from Lone Willow Slough.
[3] San Joaquin and Kings River Canal Company.
[4] Areas included with San Luis Canal Company and Temple Slough diversions.
[5] Carries some water for San Luis Canal Company.
[6] Carries some water for San Joaquin and Kings River Canal Co.
[7] 6000 acres of grass lands recently irrigated from Chowchilla Canal.



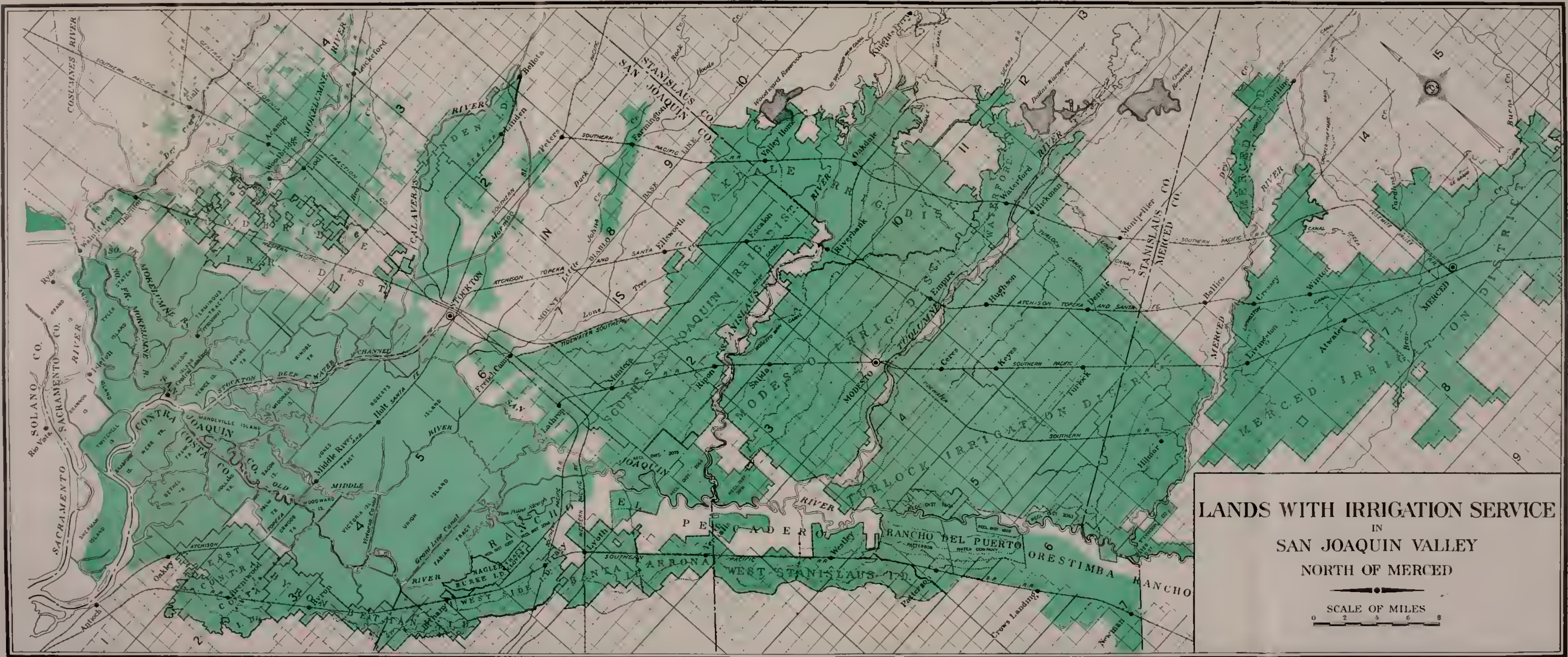


LANDS WITH IRRIGATION SERVICE FROM SAN JOAQUIN RIVER ABOVE MOUTH OF MERCED RIVER

SOURCES OF INFORMATION FOR LANDS CONSIDERED RIPARIAN

1. Lands described in connection with Suit No. 11,630, San Francisco, in complaint of Amelia Herminghaus vs. Southern California Edison Company
2. Riparian lands as set forth in a recent decision in the case of Miller and Lux vs. Madera Irrigation District, Suit No. 25, 729, Fresno County
3. Lands decreed riparian and specifically described in the judgment in the case of Miller and Lux and San Joaquin and Kings River Canal and Irrigation Company vs. Jefferson G. James, Suit No. 2,006, Fresno County.
4. Riparian lands of Chowchilla Farms, Inc., as described in case 9,262, Merced County; Chowchilla Farms, Inc., vs. Fresno Irrigation District.
5. Riparian lands as described in a contract agreed to between Chamberlain and Potter and the San Joaquin River Water Storage District, in procedure for the formation of that district. Also described in Case No. 6,064, Merced County; Saline A. Chamberlain vs. Southern California Edison Company
6. Riparian lands described in Case No. 4,862, Merced County, entitled W. W. Wright vs. Madera Irrigation District.
7. Riparian lands described in Case No. 4,626, Merced County, entitled Rio Tierra Investment Company vs. Madera Irrigation District.
8. Riparian lands set up in Case No. 4,635, Merced County, entitled J. A. Turner and A. J. Turner vs. Madera Irrigation District.
9. Lands described in Case No. 4,360, Merced County, entitled John H. Dugan vs. Madera Irrigation District.
10. Lands considered riparian, described in a petition for exclusion at hearing held November 12, 1926, in procedure for the formation of San Joaquin River Water Storage District.
11. Riparian lands set up in Case No. 4,717, Merced County, entitled J. J. Stevinson, a corporation vs. Madera Irrigation District.
12. Riparian lands as set up in Case No. 7,811, Merced County, entitled Charles S. Howard Company vs. Southern California Edison Company

80997


LANDS WITH IRRIGATION SERVICE
IN
SAN JOAQUIN VALLEY
NORTH OF MERCED
SCALE OF MILES
0 2 4 6 8
STOCKTON
MODESTO
MERCED
Lodi
Lockeford
Bellota
Linden
Farmington
Valley Home
Oakdale
Riverbank
Escalon
Ripon
Salida
Empire
Waterford
Hickman
Montpelier
Hughson
Denair
Ceres
Keyes
Turlock
Hilmar
Ballico
Livingston
Cressey
Winton
Atwater
Snelling
Manteca
Lathrop
French Camp
Tracy
Vernalis
Westley
Patterson
Crows Landing
Newman
Antioch
Oakley
Brentwood
Byron
Rio Vista
Ryde
Isleton
Walnut Grove
Thornton
Acampo
Woodbridge
Galt
Middle River
OAKDALE IRRIG. DIST.
SOUTH SAN JOAQUIN IRRIG. DIST.
MODESTO IRRIG. DIST.
TURLOCK IRRIGATION DIST.
MERCED IRRIGATION DIST.
WEST STANISLAUS I.D.
EAST CONTRA COSTA I.D.
BYRON
WEST SIDE
NAGLEE BURKE I.D.
RANCHO DEL PUERTO
ORESTIMBA
RANCHO
EL PESCADERO
CONTRA COSTA CO.
SAN JOAQUIN CO.
STANISLAUS CO.
MERCED CO.
SACRAMENTO CO.
SOLANO CO.
SACRAMENTO RIVER
SAN JOAQUIN RIVER
MOKELUMNE RIVER
COSUMNES RIVER
CALAVERAS RIVER
STANISLAUS RIVER
TUOLUMNE RIVER
MERCED RIVER
OLD RIVER
MIDDLE RIVER
SOUTHERN PACIFIC
ATCHISON TOPEKA AND SANTA FE
WESTERN PACIFIC
TIDEWATER SOUTHERN
Woodward Reservoir
Dallas Warner Reservoir
Owens Reservoir


LAND

below the mouth of the Merced River. The Helm Canal is part of the San Luis Canal system and diverts for lands lying between the river and the areas served by the San Joaquin and Kings River Canal. The Firebaugh Canal System consists of a series of pump lifts serving lands northward from the Mendota diversion and above the Outside Canal. Below the Mendota Weir are several canals and sloughs which divert to adjacent lands. Blythe Canal and the East Side Canal serve lands on the east side; Temple and Pick Anderson sloughs serve lands on the west side. In addition to the definite diversions some areas secure water through other sloughs or by general overflow. Such areas include the Herminghaus lands above Mendota and several holdings along the river below Mendota. Table 49 gives general data on diversion capacities and areas served by these canals. Recently, 6000 acres of grass lands, not shown in the table, have been irrigated from the Chowchilla Canal.

The intake of the Gravelly Ford Canal, which has no headgate, is located near the southwest corner of the southeast quarter of Section 8, Township 13 South, Range 17 East, M. D. B. and M. The zero of a staff gage, established September 3, 1929, is set at elevation 192.00 feet, U. S. Geological Survey datum. The water surface elevation at maximum diversion is 201 feet.

The Aliso Canal diverts from the San Joaquin River at the east side of the northwest quarter of the northwest quarter of Section 22, Township 13 South, Range 16 East. The headgate is located about 1000 feet down the canal from its intake and a staff gage about 1000 feet below the headgate in the northeast quarter of the northeast quarter of Section 21. The zero of the gage is set at elevation 180.00 feet. The water surface elevation at maximum diversion is 186 feet.

Water is diverted through Brown and Lone Willow sloughs to the Columbia and Chowchilla canals. Brown Slough diverts from the San Joaquin River in the northeast quarter of the northwest quarter of Section 29, Township 13 South, Range 16 East. A headgate and a staff gage are located about 1000 feet down the canal from the intake. The zero of the gage is set at elevation 172.00 feet. The water surface elevation at maximum diversion is 176 feet. Lone Willow Slough diverts from the San Joaquin River in the southeast quarter of the northwest quarter of Section 25, Township 13 South, Range 15 East, at Whitehouse. The headgate is located at the point of diversion. A staff gage, established August 3, 1929, is located about 1500 feet down the canal from its intake in the northeast quarter of the northwest quarter of Section 25. The zero of the gage is set at elevation 164.00 feet and the water surface elevation at maximum diversion is elevation 171 feet. Brown Slough discharges into Lone Willow Slough at the headgate of the Columbia Canal in the southwest quarter of the northeast quarter of Section 23, Township 13 South, Range 15 East. The zero of a gage at the headgate is set at elevation 164.00 feet, and the water surface elevation at maximum diversion is elevation 168 feet. The Chowchilla Canal intake and headgate are located about one-half mile northerly, along Lone Willow Slough, from the Columbia Canal intake, near Whitehouse Ranch headquarters in the southeast quarter of the southwest quarter of Section 14. The gaging station at this point was discontinued August 2, 1929, and the staff gage removed.

The Firebaugh and Outside canals' intakes and headgates are located on Fresno Slough about four-fifths of a mile south of Mendota Weir, in the northeast quarter of the northeast quarter of Section 30, Township 13 South, Range 15 East. The zero of a gage on the Firebaugh Canal near its head, established February 12, 1930, is set at elevation 156.00 feet and the maximum recorded water surface elevation is 162 feet. There is a gaging station, established August 27, 1929, on the Outside Canal about one and one-half miles below its intake in the northeast quarter of the northeast quarter of Section 24, Township 13 South, Range 14 East. The zero of the gage is set at elevation 153.00 feet and the water surface elevation at maximum diversion is 159 feet.

The Main Canal, Helm Canal and Helm Ditch divert from the pool immediately above Mendota Dam in the southwest quarter of the northeast quarter of Section 19, Township 13 South, Range 15 East. The zero of a gage near the head of Main Canal is set at elevation 151.00 feet and the water surface elevation at maximum diversion is 160 feet. The Helm Canal has a drop just below its intake, on the lower side of which is located a staff gage. The zero of the gage is set at elevation 151.00 and the water surface elevation at maximum diversion is 156 feet. The Helm Ditch diverts just to the north of Helm Canal. It follows the high land adjacent to the river. The zero of a staff gage near its head is set at elevation 156.00 feet and the water surface elevation at maximum diversion is 159 feet.

The Blythe Canal is an artificial channel about six-tenths of a mile in length that diverts water from the east side of the San Joaquin River to the lower channel of Fresno River. Its point of diversion is located in the northeast quarter of the northeast quarter of Section 13, Township 11 South, Range 13 East. The zero of a gage on this canal near its head, (now discontinued) was set at elevation 122.00 feet and the water surface elevation at maximum diversion is 126 feet.

Temple Slough diverts from the west side of the San Joaquin River at a point about one-third of a mile below the Blythe Canal intake in the southeast quarter of the southwest quarter of Section 12, Township 11 South, Range 13 East. The zero of a gage below the headgate, established December 4, 1929, is set at elevation 118.00 feet and the water surface elevation at maximum diversion is 123 feet.

Chamberlain Slough diverts from the east side of the San Joaquin River below the mouth of Chowchilla River in northwest quarter of the northeast quarter of Section 31, Township 9 South, Range 13 East. The elevation of its water surface at maximum diversion is 111 feet.

Pick Anderson Slough diverts from the west side of the San Joaquin River through five channels. The locations of the points of diversion all of which are in Township 9 South, Range 12 East, and the elevations of their water surfaces at maximum diversion are set forth in a downstream order as follows:

1. Southwest quarter of the southeast quarter of Section 26, elevation 106 feet.
2. Southwest quarter of the southeast quarter of Section 26, elevation 106 feet.
3. Northeast quarter of the southwest quarter of Section 26, elevation 105 feet.

4. Northwest quarter of the southwest quarter of Section 26, elevation 103 feet.

5. Southwest quarter of the northeast quarter of Section 27, elevation 103 feet.

The San Luis Island Canal (also known as Clair Canal) is located between Salt Slough and the San Joaquin River. Its intake is located on the east side of Salt Slough in the southwest quarter of the northeast quarter of Section 14, Township 9 South, Range 11 East, at an elevation of about 95 feet. It receives water diverted from the San Joaquin River through Pick Anderson Slough and thence through Middle and Salt sloughs to its intake.

The East Side Canal diverts from the east side of the San Joaquin River in the northwest quarter of the northeast quarter of Section 17, Township 9 South, Range 12 east. The elevation of its water surface at maximum diversion is 98 feet.

As a result of extensive discussion among various interests on San Joaquin River, which were in 1929 connected with the proposed San Joaquin River Water Storage District, a suggested flow schedule was tentatively agreed upon and used in the formulation of plans for additional irrigation development. The schedule is based on the records of diversions during the different months of the year, and for various river stages. The river flow, as regulated by the upper power storage, is allocated to existing diversions in accordance with their priorities, up to an amount equal to the total requirements. Diversions totaling 5000 second-feet are listed.

A modified flow schedule was filed with the California Railroad Commission by the San Joaquin and Kings River Canal Company, in connection with an application by that company for authority to increase water rates. This schedule is mentioned in the commission's decision No. 22228 of March 19, 1930. It provides for the use of power released waters by the company, based upon an apparently reasonable and practicable exchange for use by Miller & Lux, Inc., of certain amounts of the company's natural flow waters in the early part of the irrigation season when usually all such waters are not required by the utility consumers. Operation under this flow schedule as stated in said decision was limited to the irrigation season of 1930, but might eventually result in minor modifications of the original San Joaquin River Water Storage District schedule, as herein applied. Such modifications would have resulted in an annual average water yield of about 20,000 acre-feet less for the crop lands involved than under the original schedule.

In Table 50 are summarized the maximum water yields for the crop lands that would have been obtained by the application of the proposed San Joaquin River Water Storage District schedule, to the stream flow, as regulated by existing power storage, for the period 1910–1927. The area irrigable under each right represents the land now considered for service thereunder. The totals differ from the corresponding figures shown in Table 49 because in Table 50 grass lands under the Blythe Canal are included with the crop lands. Blythe Canal waters are used in conjunction with crop land waters from the Chowchilla Canal. At this time it appears that it would not be feasible to differentiate between the two uses of water in this particular area as portions of the respective grass land and crop land are utilized together in individual enterprises. The estimated total diversion requirements for the 309,000 acres classified as crop lands, in Table 50, are 895,700 acre-feet per season.

TABLE 50

AREAS OF IRRIGATION SERVICE, CROP LAND REQUIREMENTS AND AVERAGE SEASONAL SCHEDULE YIELD FOR DIVERSIONS FROM SAN JOAQUIN RIVER, ABOVE MOUTH OF MERCED RIVER, 1910-1927

Service area	Crop lands		Average seasonal schedule yield, 1910-1927, in acre-feet	Grass land area, in acres
	Area, in acres	Maximum seasonal demand, in acre-feet		
Riparian lands above Gravelly Ford	5,000	12,200	No schedule	
Chowchilla Canal	10,000	51,200	51,200	
San Joaquin and Kings River Canal	155,500	482,000	495,600	37,500
Columbia Canal	16,000	40,000	43,200	
San Luis crop lands	47,500	117,700	135,700	
Firebaugh Canal	24,000	60,000	59,500	
Lone Willow Slough residual area			56,100	23,000
Aliso Canal			63,100	22,000
Gravelly Ford Canal			37,900	14,000
Fresno Slough areas	14,000	33,600	27,600	
San Luis grass lands			120,900	58,500
East Side Canal	20,000	48,000	54,200	
Blythe Canal (grass land)	14,000	42,000	42,300	
State Game Farm	3,000	9,000	9,000	
Herminghaus grass lands (overflow lands)				16,000
Chamberlain-Potter (overflow lands)				2,000
Lower East Side (overflow lands)				25,000
Lower West Side (overflow lands)				20,000
Totals	309,000	895,700		218,000

Table 51 shows the seasonal yield which would have been obtained from the San Joaquin River by the crop lands and grass lands during the 12-year period, 1917–1929, under the proposed schedule, with existing conditions of irrigation and power development.

TABLE 51

WATER YIELD OF SAN JOAQUIN RIVER IN ACCORD WITH PROPOSED SCHEDULE OF SAN JOAQUIN RIVER WATER STORAGE DISTRICT

Season	Crop land water, in acre-feet	Grass land water, in acre-feet	Surplus water, in acre-feet	Total impaired flow at Friant, in acre-feet
1917–1918	864,000	640,500	41,400	1,545,900
1918–1919	728,500	626,000	8,600	1,363,100
1919–1920	843,600	429,400	27,600	1,300,600
1920–1921	870,500	671,700	17,700	1,559,900
1921–1922	892,100	974,300	413,100	2,279,500
1922–1923	886,900	772,200	24,400	1,683,500
1923–1924	460,800	193,200	0	654,000
1924–1925	861,100	408,700	3,700	1,273,500
1925–1926	736,900	494,800	300	1,232,000
1926–1927	878,800	912,000	94,900	1,885,700
1927–1928	739,400	480,600	9,400	1,229,400
1928–1929	768,300	148,100	0	916,400
12-year averages	794,200	562,700	53,400	1,410,300

Lands with Irrigation Service in San Joaquin Valley, North of Merced.

Irrigation development, in this section of the lower San Joaquin Valley, segregates itself naturally into areas obtaining water from the main San Joaquin River, from east side tributaries and from San Joaquin Delta.

Service from Main San Joaquin River—On the west side of the lower San Joaquin Valley, diversions below the mouth of the Merced River are made by pumping from the main San Joaquin River. The water supply comprises the flow of the main San Joaquin River and its east side tributaries. The low water flow consists largely of return water from irrigation. From the south to the north the more important irrigation systems above the delta area are those of the Patterson Water Company and the West Stanislaus, Banta Carbona, and West Side irrigation districts. These systems pump by multiple lifts to maximum total heights of about 175 feet, in some cases. They serve practically all of the west side area up to the elevation of their maximum lifts, from vicinity of Patterson to Tracy. A total area of about 43,000 acres was irrigated by these systems in 1929.

Service from East Side Tributaries—Development along the east side of the lower San Joaquin Valley has been effected almost entirely under the irrigation district form of organization. These districts have been described in detail in another report [1] so that extensive discussion here is not required. In general, the conditions are materially different from those in the upper San Joaquin Valley and the methods used are therefore different. Surface storage works have been constructed on the three main tributary streams. The supply afforded by these reservoirs, together with the utilization of the return flow in the lower stream channels, enables the late summer requirements to be supplied from stream diversion rather than by use of ground water storage. As the canal systems cover the larger part of the area and afford adequate surface supplies, there is little development of wells by individual landowners. Ground water use for irrigation occurs mainly in the north end of the area near Stockton. Such ground water pumping, as practiced in other areas, is mainly for drainage to remove excess water resulting from irrigation rather than as a source of supplemental water, although a considerable amount of the water so pumped for drainage is being utilized also for irrigation. Such drainage pumping is handled by the district organizations rather than by the individual landowners.

The six irrigation districts on the east side of the lower San Joaquin Valley include nearly all of the better lands between the rolling hardpan or residual soils on the east and the lower and generally alkaline areas near the valley trough. Lands to the north of these districts are within the lower valley areas where the rainfall is larger and irrigation canal systems have not been generally constructed.

The Merced Irrigation District covers lands south of Merced River with a small area on the north side. The total area in the district is 189,682 acres of which 134,379 acres were irrigated in 1929. The crops

[1]Bulletin No. 21, "Irrigation Districts of California," Division of Engineering and Irrigation, State Department of Public Works, 1929.

are well diversified. The district has constructed storage on Merced River at Lake McClure of 279,000 acre-feet capacity. The direct stream flow with the storage and some re-use of water, pumped for drainage, furnish a generally adequate and well sustained water supply for this district. The district extends from the more rolling hardpan lands at the east to the lower and generally alkaline lands at the west. At the south there is an area between the Merced District and Chowchilla River for which canal facilities have not been provided. The recently organized El Nido Irrigation District comprises 9450 acres of this area, of which 4000 were irrigated in 1929. It has arranged to secure surplus water from the Merced District. There is some additional development by individual pumping plants, but these represent only a small part of the gross area outside of the El Nido District.

The Turlock Irrigation District embraces 181,498 acres extending from the Tuolumne River to the Merced River. There were 133,750 acres irrigated in 1929. This district and the Modesto District have constructed joint storage at Don Pedro on Tuolumne River. Pumping for drainage is also partly used for irrigation. The Turlock district covers the better lands between the Tuolumne and Merced Rivers and between the upper hardpan and lower alkali areas.

The Tuolumne River also supplies lands on the north side, in the Modesto and Waterford irrigation districts. The Modesto District includes 81,183 acres of which 66,370 acres were irrigated in 1929. The water supply is obtained from direct flow and storage with some ground water pumping for drainage. The Waterford District includes 14,110 acres of which 5079 acres were irrigated in 1929. This district covers lands near the river and above the Modesto District. Its boundaries are more irregular in order to include the valley areas in the more rolling topography of the lower foothills.

The Stanislaus River is the source of supply for the Oakdale and South San Joaquin irrigation districts. These districts have constructed storage jointly at Melones. The Oakdale Irrigation District has a gross area of 74,240 acres, of which 23,321 acres were irrigated in 1929. This district lies on both sides of Stanislaus River in the main valley and extends into some irregular areas of valley land, within the generally lower foothill areas. On the south side of the river the Oakdale District extends to the boundaries of the Modesto and Waterford districts. On the north side it extends to the eastern boundary of the South San Joaquin Irrigation District.

The South San Joaquin Irrigation District includes 71,112 acres, of which 54,340 acres were irrigated in 1929. In addition, there were 14,400 acres of nonirrigated crop land which are largely subirrigated. There is some pumping for drainage. The district covers the areas below the Oakdale District on the north side of the Stanislaus River.

The lower San Joaquin Valley, as this term is used herein, extends northward on the east side of the valley to the Cosumnes River, although it is proposed that the area north of the lands served from the Stanislaus River shall have deficiencies in water supply met by diversions from the Sacramento Valley. This area includes the lands adjacent to Calaveras and Mokelumne rivers. Present development is mainly by pumping from individual wells. The Woodbridge Irrigation District includes 13,851 acres of lower lands near the

Mokelumne River served by canal diversion from that stream of which 6184 acres were irrigated in 1929. The recently organized Linden Irrigation District of 13,700 acres proposes to secure water from the Calaveras River. About 6000 acres were irrigated in 1929.

Service from San Joaquin Delta—North of the areas served by the main San Joaquin River, on the west side of the lower San Joaquin Valley, are the Tracy-Clover, Naglee-Burk, Byron-Bethany and East Contra Costa irrigation districts pumping water from delta sloughs, supplied principally through Old River, with both Sacramento River and San Joaquin River waters. These systems pump by multiple lifts to maximum total heights of about 175 feet in some cases. They serve practically all of the west side area, up to the elevation of their maximum lifts, from the vicinity of Tracy to Oakley. A total area of about 28,000 acres was irrigated by these systems in 1929.

In Chapter III, a portion of the main Sacramento-San Joaquin Delta is listed with areas within the San Joaquin Valley. The gross area is 279,000 acres and the net irrigable 257,000 acres. Irrigation development in this area is fully covered in another report.* The entire area is reclaimed swamp and overflow land. Irrigation water is obtained either by pumping or siphoning from the channels surrounding or adjacent to the various tracts. A large part of the area is subirrigated naturally. There were 218,800 acres irrigated in the San Joaquin Delta, in 1929. As the larger part of the water supply for this area is derived from Sacramento Valley sources, the discussion of its development and the plans for its future service have been included in another report.**

Foothill Areas.

There are some irrigated and irrigable areas within the foothills of the Sierra Nevada adjacent to the lower San Joaquin Valley. Although there are some lands in the west side foothills that might be rated as irrigable, as far as soil is concerned, the lack of local water supplies has prevented development.

The results of a classification of the east side foothill areas have been presented in Chapter III. These areas all lie above the lands served by existing diversions for valley lands. There is very little irrigation in the foothills south of the Tuolumne River. Canals built for mining and used for some irrigation are now operated mainly for power purposes and still serving some lands. Such systems include those now owned by the Pacific Gas & Electric Company near Sonora and by the Utica Mining Company near Angels Camp. There are also some smaller diversions for irrigation of the scattered areas of irrigated bottom lands along the various local streams. The total area so irrigated is relatively small. The areas irrigated in Tuolumne, Calaveras and Amador counties, in 1929, totaled 6100 acres, in accord with the survey by the State.

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta," Division of Water Resources, State Department of Public Works.

** Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works.

Growth of Irrigated Area.

The growth of irrigation in the lower San Joaquin Valley is indicated by the census returns, which have been reported by counties. No means are available for determining what portion of the irrigated areas of counties lying only partially within the basin should be credited to other sections. For this reason, no data are included for Sacramento, El Dorado and Alameda counties, the larger part of whose agricultural lands lie outside of the San Joaquin River Basin. It is believed, however, that returns for Merced, Stanislaus, San Joaquin and Contra Costa counties indicate the general progress of irrigation development in the lower San Joaquin Valley. The available data are shown in Table 52.

TABLE 52

GROWTH OF IRRIGATED AREAS IN LOWER SAN JOAQUIN VALLEY, BY COUNTIES

County	Area irrigated, in acres				
	From U. S. Census of				State crop survey, 1929
	1899	1909	1919	1929	
Merced	111,330	151,998	212,851	318,244	236,300
Stanislaus	17,505	84,015	197,249	241,712	264,800
San Joaquin	18,466	59,811	183,923	281,629	410,300
Contra Costa	----------	26,856	33,079	53,159	*67,500
Totals	147,301	322,680	627,102	894,744	978,900

*In San Joaquin River Basin, only.

For the special census of 1902 and the regular censuses of 1919 and 1929, the data have been segregated by stream sources and are shown in Table 53.

TABLE 53

GROWTH OF IRRIGATED AREAS IN LOWER SAN JOAQUIN VALLEY, BY STREAM BASINS

Data from U. S. Census Reports

Stream	Area irrigated, in acres		
	1902	1919	192
San Joaquin River	129,647	642,261	471,789
Merced River	19,636	65,151	140,131
Tuolumne River	(1)	165,533	207,347
Stanislaus River	13,840	75,359	81,981
Calaveras River	(1)	13,323	8,327
Mokelumne River	5,558	36,848	85,172
Cosumnes River	(1)	3,259	7,885
Other tributaries of San Joaquin River	41,241	55,015	143,349
Totals	209,922	1,056,749	1,145,981

[1] Not reported separately in 1902.

In the eastern foothills, adjacent to the lower San Joaquin Valley, there has been very little change in the area irrigated during the past 30 years. Available data are shown in Table 54. The area decreased in the last decade to about the amount irrigated in 1899 and 1909, showing practically no permanent increase.

TABLE 54

GROWTH OF IRRIGATED AREAS IN EASTERN FOOTHILLS OF LOWER SAN JOAQUIN VALLEY, BY COUNTIES

County	Irrigated area in acres, from United States Census of			
	1899	1909	1919	1929
Mariposa	574	376	66	26
Tuolumne	1,381	2,035	2,892	1,596
Calaveras	1,476	1,275	2,859	1,996
Amador	1,167	826	326	678
Totals	4,598	4,512	6,143	4,296

Present Irrigated Crops.

The detailed results of the crop classification for 1929 have been presented, by counties, in Table 20, Chapter III. The irrigated areas in the lower San Joaquin Valley, exclusive of portions in Sacramento and El Dorado counties and 194,300 acres in the San Joaquin Delta portions of San Joaquin and Contra Costa counties, are summarized by crops in Table 55.

TABLE 55

IRRIGATED CROPS IN LOWER SAN JOAQUIN VALLEY, 1929

Crops	Area, in acres
Citrus	200
Deciduous	107,500
Grapes	116,000
Grain	131,200
Alfalfa	211,600
Field	31,500
Cotton	66,400
Irrigated Pasture	61,500
Truck	84,200
Rice	15,600
Unclassified	6,100
Total	831,800

The table illustrates the wide diversity in crop production within the lower San Joaquin Valley. Practice varies from the culture of deciduous fruits of nearly all of the commercial varieties to the wild flooding of grass lands for pasturage purposes. Grape vineyards are prevalent throughout the area. They are devoted to the culture of grapes of the raisin, wine, and table varieties.

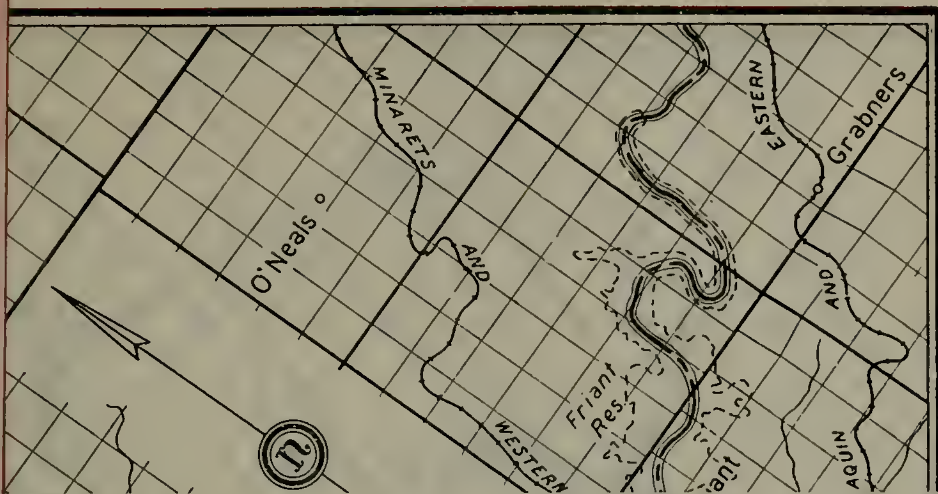
Among the deciduous fruits, peaches, prunes, figs, walnuts and almonds are the most important. Alfalfa is grown both for local use in connection with dairying and for exportation. The long growing season and adequate water supply results in exceptionally large yields. A wide variety of annuals is grown, including grain, cotton, rice, truck and field crops. In addition to the 131,200 acres of irrigated grain shown in Table 55, there were 259,600 acres of dry farmed grain in the lower San Joaquin Valley in 1929.

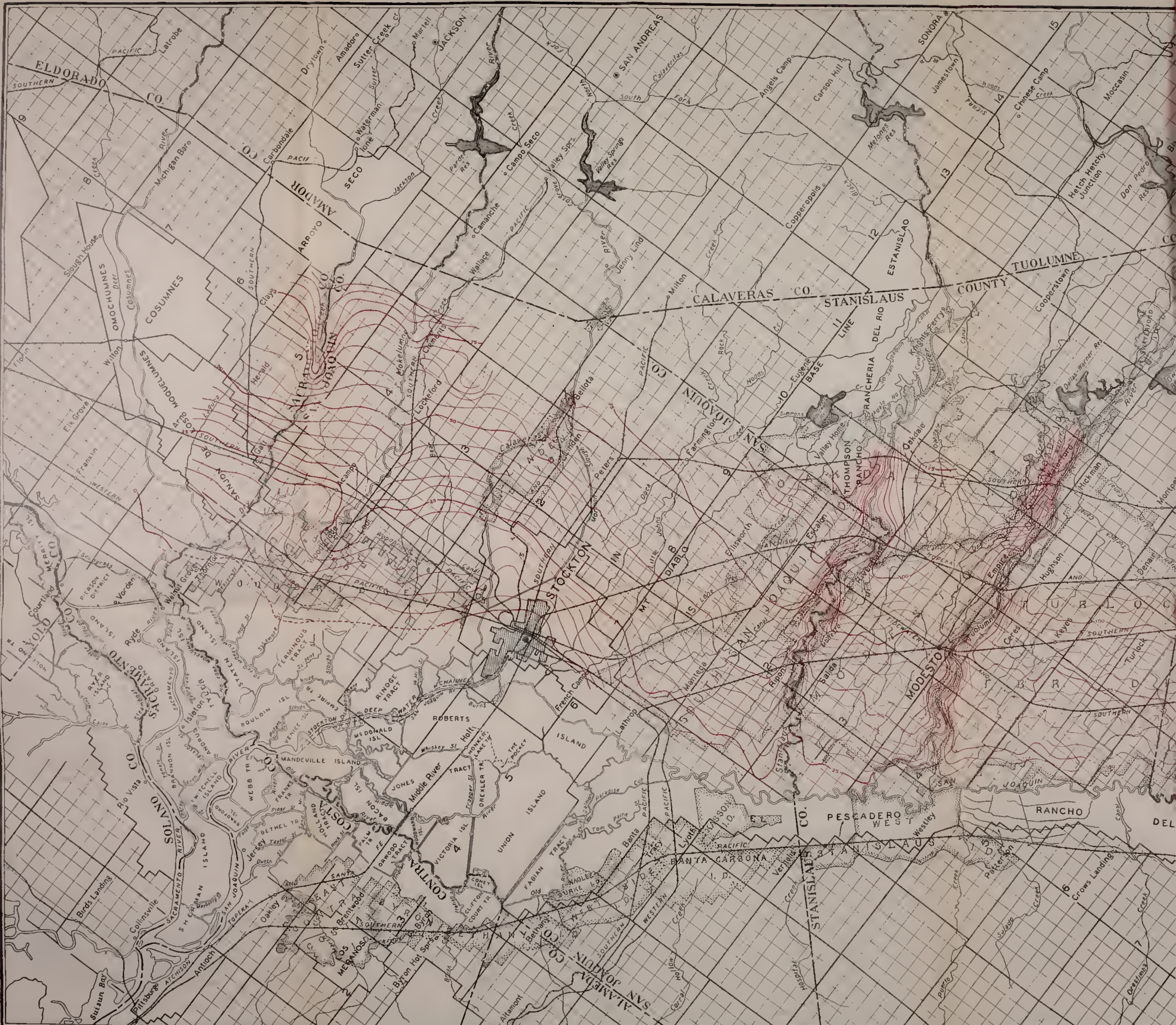
Ground Water Conditions.

Plate XXV, "Lines of Equal Elevation of Ground Water Table in Lower San Joaquin Valley, Fall of 1929," shows ground water levels for the east side of the valley. Data for showing similar lines on the west side areas are not available. On the east side of the valley practically all of the area covered by Plate XXV receives full canal service. The three principal tributary streams, Merced, Tuolumne and Stanislaus rivers, cross the area in deep channels cut below the level of the ground water in the adjacent irrigated lands. These stream channels act as drains. This is shown clearly by the extension of the ground water contours up each of these streams. In other parts of the area, the ground water contours generally parallel the ground surface contours.

Plate XI shows the zones of depth to ground water for the east side areas. Ground water is within ten feet of the surface over a large part of the area. The depth generally in these areas is from five to ten feet. Depths of less than five feet have been largely reduced by drainage pumping. There has been no ground water lowering due to overdraft. In recent years such lowering as has occurred has been beneficial as drainage.

On the west side of the valley, ground water is generally close to the ground surface in much of the canal served area south of Patterson. On the higher lands, above the canals, ground water is deeper and of uncertain quantity. North of Patterson it is sufficiently deep to give full drainage, except for a few areas along the river. There are few wells on the higher land and practically all irrigation water is secured by pumping from the San Joaquin River.


MINARETS
AND
WESTERN
O'Neals
EASTERN
AND
Grabners
Friant
Res.
AQUIN



ELDORADO CO.
AMADOR CO.
Latrobe
Drytown
Amadoro
Sutter Creek
Martell
JACKSON
Ione
Carbondale
Michigan Bar
Slough House
Arroyo
SECO
Camanche
Campo Seco
Wallace
Valley Sprs
Valley Springs Res
SAN ANDREAS
Angels Camp
Carson Hill
Copperopolis
SONORA
Jamestown
Chinese Camp
Moccasin
Melones Res
Hetch Hetchy Junction
Don Pedro Res
CALAVERAS CO.
STANISLAUS COUNTY
TUOLUMNE
Milton
Jenny Lind
Coopersown
Knights Ferry
ESTANISLAO
DEL RIO
RANCHERIA
THOMPSON RANCHO
Oakdale
Valley Home
Farmington
Eugene
Bellota
Peters
Clays
Herald
Galt
Arno
Elk Grove
Franklin
Florin
Wilton
OMOCHUMNES
COSUMNES
MOQUELUMNES
Lockeford
Lodi
Woodbridge
Acampo
Thornton
Walnut Grove
Vorden
Courtland
Ryde
Isleton
YOLO CO.
SACRAMENTO CO.
SOLANO CO.
Rio Vista
Collinsville
Birds Landing
Pittsburg
Antioch
Oakley
Brentwood
Byron Hot Sprs
Bethany
Altamont
CONTRA COSTA CO.
ALAMEDA CO.
SAN JOAQUIN CO.
STOCKTON
French Camp
Lathrop
Manteca
Ripon
Salida
Escalon
Ellsworth
MT DIABLO
MODESTO
Empire
Hughson
Ceres
Keyes
Turlock
Hickman
Waterford
Denair
Montpelier
Westley
Patterson
Crows Landing
Vernalis
STANISLAUS CO.
PESCADERO
WEST
BANTA CARBONA I.D.
Banta
RANCHO
DEL
ROBERTS ISLAND
UNION ISLAND
VICTORIA ISL
MANDEVILLE ISLAND
JONES TRACT
MEDONALD ISL
RINDGE TRACT
TERMINOUS TRACT
BOULDIN ISL
STATEN ISLAND
TYLER ISLAND
GRAND ISLAND
SHERMAN ISLAND
WEBB TR
BRANNON ISL
BETHEL TR
HOLLAND TRACT
BACON ISL
PALM TR
Jersey
Middle River
Holt
SOUTHERN
PACIFIC
WESTERN
ATCHISON
TOPEKA
SAN JOAQUIN RIVER
SACRAMENTO RIVER
DEEP WATER CHANNEL
Suisun Bay
Tracy
Herald
Roberts

80997


LINES OF EQUAL ELEVATION
OF
GROUND WATER TABLE
IN LOWER SAN JOAQUIN VALLEY
FALL OF 1929
SCALE OF MILES
0 2 4 6 8 10
MERCED
MADERA
MARIPOSA
STANISLAUS
FRESNO

CHAPTER V

WATER REQUIREMENTS

The uses of water in the San Joaquin River Basin are many. They include domestic, municipal, irrigation, salinity control, industrial, navigation, power development and recreational uses. Of all these uses, however, that for irrigation predominates at the present time and probably will continue to do so. Recreational and navigation uses result in no actual consumption of water and in most instances do not alter the regimen of the stream. The use for development of hydroelectric energy, while altering in some instances the regimen of the stream, does not consume any water. For domestic service alone, the unit use within small cities is practically the same as for irrigation. For industrial and commercial areas in or near municipalities, the amount of water used may be somewhat larger than for the irrigation requirements for an equivalent area. In this basin, the water requirements for present and future ultimate developments have been based on irrigation use. It is believed that on this basis ample water would be provided for all uses, except that for salinity control in the Sacramento-San Joaquin Delta. In the State Water Plan, provision for that requirement is made primarily from the Sacramento River Basin.*

There is considerable variation both as to rate and period of use of water for various purposes. For irrigation, the period of use varies in different parts of the State. In the San Joaquin Valley, the greater part of the irrigation demand occurs during the months of March to October. However, irrigation is practiced in certain sections whenever water is available, even during the winter months.

Water requirements, for any particular area, vary not only in amount with the use to which the water is put, and in monthly demand, but also with the point at which the water is measured. The geographic position of the source of supply in relation to point of use, methods of conveyance, the extent of the area and the opportunity afforded for reuse of water controlled by the topographic, geographic, and geologic conditions are factors that have an important bearing on water requirements. For these reasons, variations in treatment of the problems for the different areas necessitated the employment of different terms of use in this report, as follows:

> "Irrigation requirement" is the amount of water in addition to rainfall that is required to bring a crop to maturity. This amount varies with the crop to be supplied and the point at which the water is measured. As related to the point of measurement, it is the "gross allowance," "net allowance," or "net use." These

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, Department of Public Works, 1931.

terms together with the term "consumptive use," are defined as follows:

"Gross allowance" designates the amount of water diverted at the source of supply.

"Net allowance" designates the amount of water actually delivered to the area served.

"Consumptive use" designates the amount of water actually consumed through evaporation and transpiration by plant growth.

"Net use" designates the sum of the consumptive use from artificial supplies and irrecoverable losses.

Unit Irrigation Requirements.

Irrigation requirements of California lands have been a subject of study by Federal and State agencies for many years. Much valuable data on the use of water for various crops under varying climatic and soil conditions have been collected and compiled. These data have been published in most instances. The Division of Engineering and Irrigation, Department of Public Works, made an investigation of irrigation requirements of the lands of the State in 1921.* These studies have been continued by the Division of Water Resources, since the publication of that report. Information on areas in the Sacramento Valley and portions of the San Joaquin Valley is published in the annual reports of the Sacramento-San Joaquin Water Supervisor.

In arriving at unit values for irrigation requirements of lands in the San Joaquin River Basin full use was made and consideration given to all those published and unpublished data. In addition to such data, however, detailed analyses and studies were made during this investigation of the use of irrigation water under actual operating conditions on more than one million acres of land in localities extending from the San Joaquin Delta to Kern River area in the southern end of the valley. The area on which the uses of water were determined represents one-half of the present irrigated area in the valley. These analyses have been discussed and the results thereof set forth in considerable detail for the upper San Joaquin Valley, in Chapter IV. Information on the other sections is presented later in this chapter. It should be pointed out that the areas studied are intensively developed, contain diversified crops, utilize various methods of obtaining supplies and are representative of practicable irrigation operations.

In estimating the irrigation requirements of the San Joaquin River Basin, it was divided into four sections; namely, upper San Joaquin Valley floor, lower San Joaquin Valley floor, foothill areas and San Joaquin Delta. The requirements for the basin will be discussed under these headings.

Upper San Joaquin Valley Floor—The upper San Joaquin Valley is the southern portion of the valley extending on the east side as far north as the Chowchilla River and on the west side to a line extending from Mendota to Oro Loma. In these studies, it embraces hydrographic divisions 1, 2, 3, 4, 5, 5B and 6. It is an area in which the tributary run-off is inadequate to meet present water requirements and in which full development will be possible only with importation of

* Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, 1921.

water from distant sources at relatively high costs. Along the eastern side of the valley, the topographic and geologic characteristics of the basin are such that extensive underground storage capacity is available. The development of ground water supplies, drawn from such storage, adds to the extent to which the locally tributary run-off may be efficiently utilized within the area under consideration. Where adequate ground water storage is available, the required surface inflow is equal to the net use. On the western slope of the valley, a large area of land overlies subsoil of such chemical constituents that the use of shallow ground water would be injurious to irrigated crops. Therefore, the application of water to these lands would be made on the basis of actual plant needs and the net allowance would exceed consumptive use only by the amount of percolation losses within the area. The inability to recover percolation losses makes it necessary to estimate on net use without recovery of percolation. This area has extremely limited local water resources and, if developed extensively, would require the importation of practically its entire supply.

On the eastern slope of the valley, records, continuous in most areas since 1921, of the extent of irrigation development effected through the utilization of surface and ground water supplies, together with those of the conditions of underground storage, afford the basis for estimating the average net use. A study of this subject has been presented in Chapter IV, based on data collected for all the developed areas along the eastern side of the valley and covering the period, 1921–1929. These data consist of the annual records of surface inflow, the areas irrigated and the depths to ground water in some 4000 wells scattered throughout the region. The following values of net use are summarized from Chapter IV and are based on present irrigation practice and use in representative areas intensively developed to diversified crops in the upper San Joaquin Valley:

Area	*Seasonal net use in acre-feet per acre*
Fresno Irrigation District	1.95
Consolidated Irrigation District	1.90
Alta Irrigation District	1.90
Kaweah River Area	2.17
Deer Creek Area	2.0
McFarland-Shafter Area	2.0

The foregoing figures are supported by a value of about 2 acre-feet per acre obtained in the Turlock Irrigation District in the lower San Joaquin Valley, where measurements of surface diversion into the district, the measured outflow and records of the net area of irrigated land, made possible the calculation of the seasonal net use per acre. In making the crop survey for determining the net area of irrigated land in that district, highways, railroads, county roads, incorporated and unincorporated towns, main canals, laterals, sublaterals, and building and minor uncropped areas of more than two acres were excluded. Private roads and ditches and building and minor uncropped areas of less than two acres situated within irrigated areas were included. The net area so estimated equals about 75 per cent of the gross irrigable area of the district. It is concluded, therefore, that while the net use value varies for different crops, a reasonable estimate of the seasonal net use for the types of crops now grown in the upper San Joaquin

Valley is two acre-feet per acre. In estimating the water requirements of the upper San Joaquin Valley, this figure has been applied to the net area of irrigable land in obtaining the average seasonal allowances.

This basis of estimating the water requirement for the area does not mean that the actual delivery of water upon irrigated land would be at a uniform rate, or restricted to two acre-feet per acre per season. On the contrary, it is recognized that, dependent upon the kind of crop served and the type of soil and subdrainage conditions, seasonal applications of water vary from a minimum of less than two acre-feet per acre to a maximum of perhaps as much as 100 per cent in excess of that figure. In any case, the only water actually used is that which supplies the needs of plant transpiration and surface evaporation. On nonabsorptive soils, applications in excess of these needs result in surface run-off to adjacent lands or drainage systems. On absorptive soils such excess applications are, to a large extent, accounted for by percolation losses which constitute one of the principal sources of replenishment to the underlying ground water. In areas where it is feasible to recover these percolation losses by pumping, the application of the water so recovered constitutes a reuse of the original supply and makes for a high degree of utilization, the limit of which is reached when the net use of water equals the consumptive use. The essential element of such a plan of utilization is the availability of adequate underground storage capacity so located that water drawn therefrom can be utilized upon overlying or adjacent lands.

Lower San Joaquin Valley Floor—The lower San Joaquin Valley is that portion of the valley extending northerly from the upper San Joaquin Valley to the southern limits of the Sacramento Valley. It comprises hydrographic divisions 7 to 13, inclusive. In Chapter IV, it has been pointed out that the water supplies for the present extensive irrigation development are generally adequate and dependable. These supplies are obtained from the San Joaquin River and its east side tributaries, for the most part, by surface diversions. Pumping from underground basins is not practiced extensively. Surface supplies are the primary sources. Pumping from wells is supplemental and of secondary importance in the greater part of the area, although the use of ground water for irrigation in connection with drainage operations is becoming more important each year. The water requirements, therefore, have been estimated on the basis of furnishing a full surface irrigation supply to the entire irrigable area in the valley.

The unit values of irrigation requirements within the valley vary with the geographic location and also with the topographic location in relation to sources of supply. These variations will be pointed out as the requirements for each hydrographic division are presented.

In hydrographic divisions 8, 9 and 11, the unit values for gross allowance, net allowance and net use have been taken as 3.3, 2.4, and 1.9 acre-feet per acre per season, respectively. These values are based largely on the results of a detailed analysis of irrigation use in the Turlock Irrigation District (181,500 acres) under actual operating conditions for the irrigation season of 1929. In that analysis, full and complete data were available on diversions, irrigated areas, and return waters.

In Hydrographic Division 7, the foregoing values for gross and net allowances were used for the present irrigated areas on the west side of the San Joaquin River lying southerly from the mouth of the Merced River. However, a higher value of 2.1 acre-feet per acre per year for net use was obtained by using a return flow factor of 35 per cent applied to the figures for gross allowance. For the remaining lands in Hydrographic Division 7, lying on the western side of the San Joaquin River, unit values of 2.0, 1.8 and 1.6 acre-feet per acre per season were used for gross allowance, net allowance and net use, respectively. These values were used also for Hydrographic Division 10, consisting of the uplands lying to the west of the San Joaquin Delta. The foregoing unit values were deduced from measured diversions and net applications on intensively developed lands now served by pumping systems of West Stanislaus, Byron-Bethany, and East Contra Costa irrigation districts.

In hydrographic divisions 12 and 13, the unit values for irrigation requirements are based on data and information obtained on irrigation operations in the Mokelumne River area in the investigation made by the U. S. Geological Survey during the period 1926 to 1929 and published in Water Supply Paper 619. In that paper, average weighted unit values of seasonal quantities of water pumped from wells on 82 different farms are set forth. These values are 1.34 acre-feet per acre for vineyards and orchards and 3.06 for alfalfa and miscellaneous crops. These unit values were applied to respective areas of irrigated crops listed in the 1929 crop survey for hydrographic divisions 12 and 13. The resulting weighted average value was 1.5 acre-feet per acre irrigated per season. This figure was used as the net use value in estimating the ultimate water requirements. The lands in these divisions are now irrigated largely by pumping from ground water. By assuming surface supply diversions that would result in an annual return flow factor of about 40 per cent, a gross allowance requirement of 2.7 acre-feet per acre per season was obtained. The seasonal net allowance was estimated at 1.8 acre-feet per acre.

Foothill Areas—In the irrigation of foothill lands, conveyance and application losses are in general relatively large because of the type of conduits generally used and of the uneven and sloping character of the irrigated lands. It is estimated that of the total amount of water diverted from the streams for irrigation use in the foothill areas, about 40 per cent is returned ultimately to the natural stream channels and is available for reuse. These conditions have been given full consideration in estimating the irrigation requirements of the foothill areas.

The unit values for irrigation requirements for the foothill areas are based entirely on data given in Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation. In that bulletin, an average annual net duty of 1.75 acre-feet per acre is given for the Sierra foothills and rolling plains east and south of the San Joaquin Valley floor. The area included in hydrographic divisions 6A, 8A, 9A and that portion of 11A in the Tuolumne River watershed of this report, corresponds in general to the foothill area set forth in Bulletin No. 6. Therefore, the value of seasonal net use for these areas has been assumed and taken as approximately the net duty or 1.8 acre-feet per acre. Assuming that the figure for seasonal net use is 60 per cent of the seasonal diversion which is allowing for 40 per cent conveyance and application losses, a figure for seasonal gross allowance of 3.0 acre-feet per acre is obtained. The seasonal net allowance for these hydrographic divisions is estimated at 2.4 acre-feet per acre.

In Bulletin No. 6, the average annual net duty for the Sierra foothills and rolling plains east and west of the Sacramento Valley floor is given as 1.50 acre-feet per acre. The climatic and soil conditions of the area included in hydrographic divisions 12A, 13A and that portion of 11A in the Stanislaus River watershed are more nearly comparable with these areas rather than those foothill areas south of the Tuolumne River. Therefore, in selecting a seasonal value of net use, the figure of 1.50, the annual net duty for the foothill area east of the Sacramento Valley floor, was adopted for these hydrographic divisions. Using a return flow factor of 40 per cent, as for the previously discussed foothill areas, a seasonal gross allowance of 2.5 acre-feet per acre is obtained. For these particular areas, the net allowance for the purposes of this report is considered to have the same value as the net use.

San Joaquin Delta—Because of the method employed in irrigating the lands of the San Joaquin Delta it is impracticable to differentiate between gross and net allowances and net use. Furthermore, in addition to use for irrigation, the water requirements for the delta include also, amounts to meet evaporation losses in the many delta channels, transpiration from tule and other natural vegetation and evaporation from levees and uncultivated land surfaces. It is estimated that during the irrigation season, the ultimate total net use of water for all demands on the entire area will average about 2.6 acre-feet per acre, and the total net use for irrigation only about 2.3 acre-feet per acre. A full discussion of this matter is given in another report,* to which reference is made.

Net Irrigable Areas.

Irrigation practice in California has demonstrated that the entire irrigable area of agricultural land in any particular project is not irrigated, even in intensively developed areas. In determining the water requirements for ultimate development of the various sections of the San Joaquin Valley, this experience has been recognized and it is not considered necessary to provide a water supply for the gross area of irrigable land set forth in Chapter III. In addition to minor areas which are not arable, such as stream channels and natural drains, an appreciable area is occupied by towns, highways, railroads, county roads, canals, ditches and incidental farm improvements such as dry yards, corrals and buildings. Furthermore, the percentage of the poorer agricultural land irrigated in any one year will be less than for the better lands. Based upon the experience of fully developed organized districts in the San Joaquin Valley, it has been determined that, in areas of good land, not over 80 per cent of the gross area will

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.

require water. In areas of poorer land the percentages will be smaller. The following factors have been used for the different classes of valley land in estimating the respective net irrigable areas:

Lands in Class 1	80 per cent
Lands in Class 2	80 per cent
Lands in Class 3	60 per cent
Lands in Class 4	20 per cent
Lands in Class 5	0

The foregoing percentages are considered to represent the maximum areas that will require a water supply under conditions of ultimate development. Some exceptions from these standards have been made in certain areas of foothill land, as set forth in Table 19, Chapter III. The application of the respective percentages to the gross areas of irrigable land, presented by hydrographic divisions in Tables 18 and 19, gives the net irrigable areas set forth in Table 56.

TABLE 56

NET IRRIGABLE AREAS IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions see Plate VI

Hydrographic division	Net area, in acres				
	Class of land				Totals
	1	2	3	4	
Upper San Joaquin Valley Floor—					
1	564,700	253,000	186,300	1,000	1,005,000
2	375,900	185,100	67,000	0	628,000
3	186,900	81,700	27,400	0	296,000
4	634,700	190,000	100,500	1,800	927,000
5	243,400	16,900	13,700	0	274,000
5 B	191,400	30,400	5,200	0	227,000
6	112,000	84,900	62,900	31,200	291,000
Totals	2,309,000	842,000	463,000	34,000	3,648,000
Lower San Joaquin Valley Floor, excluding San Joaquin Delta—					
7	244,700	99,400	38,000	25,900	408,000
8	91,500	123,300	50,200	17,000	282,000
9	147,200	107,700	57,100	0	312,000
10	57,300	8,100	3,600	0	69,000
11	128,500	85,400	46,100	0	260,000
12	161,100	40,000	16,900	0	218,000
13	20,700	76,100	29,100	1,100	127,000
Totals	851,000	540,000	241,000	44,000	1,676,000
Totals, San Joaquin Valley Floor, excluding San Joaquin Delta	3,160,000	1,382,000	704,000	78,000	5,324,000
Foothill areas—					
6 A	0	0	11,600	29,400	41,000
8 A	0	900	41,300	41,800	84,000
9 A	0	0	50,600	11,400	62,000
11 A	0	1,900	42,200	28,900	73,000
12 A	2,200	4,100	37,300	37,400	81,000
13 A	600	2,700	20,500	15,200	39,000
Totals	2,800	9,600	203,500	164,100	380,000
Totals, San Joaquin River Basin, excluding San Joaquin Delta	3,162,800	1,391,600	907,500	242,100	5,704,000
San Joaquin Delta	242,000	14,100	900	0	257,000
Totals, San Joaquin River Basin	3,404,800	1,405,700	908,400	242,100	5,961,000

For purposes of making water utilization studies, net irrigable areas in the lower San Joaquin foothill divisions have been divided further into areas located above and below the major foothill reservoir sites, as set forth in Table 57.

TABLE 57

NET IRRIGABLE AREAS IN FOOTHILL DIVISIONS ABOVE AND BELOW MAJOR RESERVOIR SITES

Hydrographic division	Net area, in acres		
	Above reservoir sites	Below reservoir sites	Totals
8 A	56,000	28,000	84,000
9 A	15,000	47,000	62,000
11 A	43,000	30,000	73,000
12 A	52,000	29,000	81,000
13 A	39,000	0	39,000

Ultimate Water Requirements.

The ultimate water requirements of the San Joaquin River Basin have been estimated and are set forth by sections in Table 58; namely, upper San Joaquin Valley floor, lower San Joaquin Valley floor, foothill areas and San Joaquin Delta. The irrigation requirements for the irrigable areas of classes 1, 2, 3, and 4 lands in the foothills and valleys were calculated by applying the per acre values for gross and net allowances and net use to the corresponding net irrigable acreages given in Table 56. The water requirements in the San Joaquin Delta were obtained from another report.* The ultimate seasonal net use for the entire Sacramento-San Joaquin Delta is estimated in Bulletin No. 26 as 1,200,000 acre-feet for the irrigation season extending from April to October, inclusive. For the San Joaquin Valley portion of the delta alone, it is estimated that the seasonal net use would be 824,000 acre-feet. In that portion of the delta there is a gross area of 328,000 acres, including channels and levees, a gross area of agricultural land of 279,000 acres and a net irrigable area of 257,000 acres.

In addition to net use requirements in the Sacramento-San Joaquin Delta, fresh water also will be required to prevent the invasion of saline water into the delta channels. It is concluded in a second report,§ that the control of saline invasion in the upper bay and delta region could be provided more feasibly and economically by fresh water releases from mountain storage to supplement the available stream flow than by any other means. Studies published in a third report† show that, in order to effect a positive control of salinity at Antioch to limit the increase of salinity at that point to a mean degree of not more than 100 parts of chlorine per 100,000 parts of water with decreasing salinity upstream, a flow of 3300 second-feet throughout the year, in the combined channels of the Sacramento and San Joaquin rivers past Antioch into Suisun Bay, would be required. This would amount to

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works.

§ Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

† Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1922.

an average annual flow of about 2,390,000 acre-feet. The salinity control requirement for the San Joaquin Valley portion of the delta is estimated at about two-thirds of the total amount or 1,590,000 acre-feet.

TABLE 58

ULTIMATE WATER REQUIREMENTS OF SAN JOAQUIN RIVER BASIN

Hydrographic division	Net irrigable Area, in acres	Gross allowance, in acre-feet		Net allowance, in acre-feet		Net use, in acre-feet	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Upper San Joaquin Valley Floor—							
1	1,005,000	2,010,000	2.0	2,010,000	2.0	2,010,000	2.0
2	628,000	1,256,000	2.0	1,256,000	2.0	1,256,000	2.0
3	296,000	592,000	2.0	592,000	2.0	592,000	2.0
4	927,000	1,854,000	2.0	1,854,000	2.0	1,854,000	2.0
5	274,000	548,000	2.0	548,000	2.0	548,000	2.0
5 B	227,000	454,000	2.0	454,000	2.0	454,000	2.0
6	291,000	582,000	2.0	582,000	2.0	582,000	2.0
Totals	3,648,000	7,296,000	2.0	7,296,000	2.0	7,296,000	2.0
Lower San Joaquin Valley Floor, excluding San Joaquin Delta—							
7 (South of Merced River)	203,000	670,000	3.3	487,000	2.4	426,000	2.1
7 (Lower west side pumping projects)	62,000	124,000	2.0	112,000	1.8	99,000	1.6
7 (West side rim lands)	143,000	286,000	2.0	257,000	1.8	229,000	1.6
10	69,000	138,000	2.0	124,000	1.8	110,000	1.6
8	282,000	930,000	3.3	677,000	2.4	536,000	1.9
9	312,000	1,030,000	3.3	749,000	2.4	593,000	1.9
11	260,000	858,000	3.3	624,000	2.4	494,000	1.9
12	218,000	589,000	2.7	392,000	1.8	336,000	1.5
13	127,000	343,000	2.7	229,000	1.8	196,000	1.5
Totals	1,676,000	4,968,000	3.0	3,651,000	2.2	3,019,000	1.8
Foothill areas—							
6 A	41,000	123,000	3.0	99,000	2.4	74,000	1.8
8 A	84,000	252,000	3.0	202,000	2.4	151,000	1.8
9 A	62,000	186,000	3.0	149,000	2.4	112,000	1.8
11 A (In Tuolumne watershed)	36,000	108,000	3.0	86,000	2.4	65,000	1.8
11 A (In Stanislaus watershed)	37,000	93,000	2.5	56,000	1.5	55,000	1.5
12A	81,000	202,000	2.5	122,000	1.5	122,000	1.5
13 A	39,000	98,000	2.5	59,000	1.5	58,000	1.5
Totals	380,000	1,062,000	2.8	773,000	2.0	637,000	1.7
Totals, San Joaquin River Basin, excluding San Joaquin Delta	5,704,000	13,326,000	----------	11,720,000	----------	10,952,000	----------
San Joaquin Delta—							
Irrigation and other uses	257,000	824,000	----------	824,000	----------	824,000	----------
Salinity control	----------	1,590,000	----------	1,590,000	----------	1,590,000	----------
Totals	257,000	2,414,000	----------	2,414,000	----------	2,414,000	----------
Totals, San Joaquin River Basin	5,961,000	15,740,000	----------	14,134,000	----------	13,366,000	----------

The wide variety of crops produced in the San Joaquin River Basin is due to varying soil and climatic conditions and geographic location with respect to available markets. This results in considerable variation both as to rate and period of use of irrigation water. The greater part of the irrigation demand occurs during the months of March to October. The estimated monthly distribution of the uses of irrigation water in per cent of seasonal total, for each hydrographic division, based chiefly on use in present irrigated areas, is set forth in Table 59.

TABLE 59

MONTHLY DISTRIBUTION OF THE USE OF IRRIGATION WATER IN SAN JOAQUIN RIVER BASIN IN PER CENT OF SEASONAL TOTAL, BY HYDROGRAPHIC DIVISIONS

Hydrographic division	Month											
	October	November	December	January	February	March	April	May	June	July	August	September
1. (Excluding west side area)	5.0	3.0	3.0	4.0	4.0	8.0	11.0	12.0	14.0	14.0	12.0	10.0
1. West side area	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
2. (Excluding west side area)	5.0	3.0	3.0	4.0	4.0	8.0	11.0	12.0	14.0	14.0	12.0	10.0
2. West side area	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
3.	5.0	2.0	2.0	3.0	3.0	8.0	11.0	13.0	15.0	15.0	13.0	10.0
4.	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
5.	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
5B.	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
6. (Excluding Columbia Canal area)	1.4	0.0	0.0	0.0	1.1	7.0	17.0	23.5	21.6	13.4	7.8	7.2
6. Columbia Canal area	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
7. West side area, south of Merced River	3.1	0.9	0.7	1.1	3.1	5.8	12.8	17.7	18.2	15.9	12.1	8.6
7. West side rim lands	4.0	0.0	0.0	0.0	0.0	5.0	7.0	19.0	19.0	19.0	16.0	11.0
7. Lower west side pumping projects	4.0	0.0	0.0	0.0	0.0	5.0	7.0	19.0	19.0	19.0	16.0	11.0
8. (Excluding area served from San Joaquin River)	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
8. Area served from San Joaquin River	3.1	0.9	0.7	1.1	3.1	5.8	12.8	17.7	18.2	15.9	12.1	8.6
9.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
10.	4.0	0.0	0.0	0.0	0.0	5.0	7.0	19.0	19.0	19.0	16.0	11.0
11.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
12.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
13.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
6A. Above major reservoir sites						Monthly use not estimated						
6A. Below major reservoir sites						Monthly use not estimated						
8A. Above major reservoir site	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
8A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
9A. Above major reservoir site	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
9A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
11A. Above major reservoir site	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
11A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
12A. Above major reservoir site, in Calaveras River Basin only	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
12A. Above major reservoir sites, excluding Calaveras River Basin	5.0	1.0	0.0	0.0	0.0	2.0	2.0	15.0	20.0	22.0	20.0	13.0
12A. Below major reservoir sites	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
13A. Above major reservoir site	5.0	1.0	0.0	0.0	0.0	2.0	2.0	15.0	20.0	22.0	20.0	13.0
13A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0

Water Requirements Under Ultimate State Water Plan.

In Table 58, are given the ultimate seasonal irrigation requirements for all classes of irrigable land in the basin. For the upper San Joaquin Valley, full development will require importation of water at relatively high costs. It is believed that service under such conditions would be justified only for the better lands. Therefore, in evolving a plan for furnishing a water supply to that region, the area of service has been taken to include only lands in classes 1 and 2 and a small area of Class 3 land suitable for citrus development which could be irrigated by diversion from Tule River. There are 7000 acres of Class 2 land in Zone 1c and 22,000 acres of Class 1 land in Zone 1e which were not included in the areas of service. These lands are unfavorably situated topographically with respect to available water supply. The lands in Zone 1c are more than 200 feet higher in elevation than the canals which serve areas north of Kern River under the State Water Plan. The lands in Zone 1e lie at elevations higher than could be served by a lift of 350 feet above the proposed Kern River diversion canal around the southern end of the valley. The remaining areas of classes 3 and 4 lands have not been included in the area for service under the State Plan for the ultimate development of the upper San Joaquin Valley. In the lower San Joaquin Valley, a region wherein water supplies are adequate if conserved, all classes of irrigable land have been included in estimating the required irrigation supply. This procedure was followed also in estimating the irrigation requirements for lands in the Sacramento River Basin.

The net areas and water requirements of lands, included for service under the ultimate State Water Plan in upper San Joaquin Valley, are set forth by hydrographic divisions in Table 60. The areas in the lower San Joaquin Valley and adjacent foothill divisions are the same as those set forth in Table 56 and their water requirements, by hydrographic divisions are the same as shown in Table 58. In Table 61, are summarized by sections the net irrigable area and water requirements for the San Joaquin River Basin as provided for under the State Water Plan. For comparison, similar information is given for the entire irrigable area in the basin.

TABLE 60

NET AREAS AND WATER REQUIREMENTS OF LANDS INCLUDED FOR SERVICE UNDER ULTIMATE STATE WATER PLAN IN UPPER SAN JOAQUIN VALLEY, BY HYDROGRAPHIC DIVISIONS

Hydrographic division	Net area, in acres					Water requirements, in acre-feet
	Class of land			Municipal areas, omitted from land classification	Totals	
	1	2	3			
1	543,000	246,000		2,000	791,000	1,582,000
2	376,000	185,000	5,000		566,000	1,132,000
3	187,000	82,000		1,000	270,000	540,000
4	635,000	190,000		5,000	830,000	1,660,000
5	243,000	17,000			260,000	520,000
5 B	191,000	30,000			221,000	442,000
6	112,000	85,000			197,000	394,000
Totals	2,287,000	835,000	5,000	8,000	3,135,000	6,270,000

TABLE 61

SUMMARY OF NET AREAS AND WATER REQUIREMENTS OF SAN JOAQUIN RIVER BASIN

Section	Areas to be served under State plan				Entire irrigable area			
	Net area, in acres	Gross allowance, in acre-feet	Net allowance, in acre-feet	Net use, in acre-feet	Net area, in acres	Gross allowance, in acre-feet	Net allowance, in acre-feet	Net use, in acre-feet
Upper San Joaquin Valley	3,135,000	6,270,000	6,270,000	6,270,000	3,648,000	7,296,000	7,296,000	7,296,000
Lower San Joaquin Valley, excluding San Joaquin Delta	1,676,000	4,968,000	3,651,000	3,019,000	1,676,000	4,968,000	3,651,000	3,019,000
Foothill areas	339,000	939,000	674,000	563,000	380,000	1,062,000	773,000	637,000
Totals, excluding San Joaquin Delta	5,150,000	12,177,000	10,595,000	9,852,000	5,704,000	13,326,000	11,720,000	10,952,000
San Joaquin Delta—								
Irrigation and other uses	257,000	824,000	824,000	824,000	257,000	824,000	824,000	824,000
Salinity control		1,590,000	1,590,000	1,590,000		1,590,000	1,590,000	1,590,000
Totals, San Joaquin River Basin	5,407,000	14,591,000	13,009,000	12,266,000	5,961,000	15,740,000	14,134,000	13,366,000

CHAPTER VI

MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

In the formulation of a plan for the development of the irrigation possibilities of the San Joaquin River Basin, full cognizance has been taken of all physical factors relating thereto. These comprise water resources, irrigable lands, water requirements, storage facilities and conveyance systems. Some of these factors have been discussed in previous chapters. In Chapter II, there is presented a complete summary of the available water resources of the basin for the 40-year period 1889–1929, including the locations, amounts and characteristics of occurrence of these waters. The classification of the lands as to their suitability for irrigation is presented in Chapter III. In Chapter V, an estimate of the water requirements for the full development of the entire irrigable area of the basin, including salinity control requirements in the San Joaquin Delta, is presented.

Relation Between Water Supply and Ultimate Water Requirements.

In order to show a general relation between the available water supply of the basin and water requirements for full development, the following data pertaining thereto have been assembled from previous chapters:

SEASONAL FULL NATURAL RUN-OFF

In acre-feet

	Available to Upper San Joaquin Valley	*Available to Lower San Joaquin Valley**	*Total San Joaquin River Basin*
Mean for 40-year period 1889–1929	3,651,200	8,328,800	11,980,000
Mean for 20-year period 1909–1929	3,128,300	7,031,300	10,159,600
Mean for 10-year period 1919–1929	2,527,400	6,019,500	8,546,900
Mean for 5-year period 1924–1929	2,355,700	5,781,300	8,137,000

* Includes run-off of San Joaquin River and delta tributaries.

NET IRRIGABLE AREA OF AGRICULTURAL LANDS

In acres

Upper San Joaquin Valley floor	3,648,000
Lower San Joaquin Valley floor	1,676,000
Foothill areas	380,000
Total, excluding San Joaquin Delta	5,704,000
San Joaquin Delta	257,000
Total San Joaquin River Basin	5,961,000

ULTIMATE WATER REQUIREMENTS

In acre-feet

	Gross allowance	*Net allowance*	*Net use*
Upper San Joaquin Valley floor	7,296,000	7,296,000	7,296,000
Lower San Joaquin Valley floor	4,968,000	3,651,000	3,019,000
Foothill areas	1,062,000	773,000	637,000
Totals, excluding San Joaquin Delta	13,326,000	11,720,000	10,952,000
San Joaquin Delta—			
Irrigation and other uses	824,000	824,000	824,000
Salinity control	1,590,000	1,590,000	1,590,000
Totals, San Joaquin Delta	2,414,000	2,414,000	2,414,000
Totals, San Joaquin River Basin	15,740,000	14,134,000	13,366,000

Table 62 shows the relation between the available water supplies and requirements of the various sections in the San Joaquin River Basin. For the upper San Joaquin Valley, the average annual water supply for the 40-year period 1889–1929, exclusive of the San Joaquin River supply which is used chiefly in the lower San Joaquin Valley, is but 50 per cent of the ultimate average annual water requirement; for the 20-year period 1909–1929, 43 per cent; for the 10-year period 1919–1929, 35 per cent; and for the 5-year period 1924–1929, 32 per cent. For the lower San Joaquin Valley and foothill areas, exclusive of San Joaquin Delta, the water supply is sufficient to meet the requirements. However, when San Joaquin Delta requirements are added, the average annual water supply, for the 40-year period only, comes close to meeting the gross allowance requirement, and the average for the 5-year period is less than the net use requirement. For the entire basin, the average annual water supplies for the 40-year, 20-year, 10-year and 5-year periods are 76, 65, 54 and 52 per cent, respectively, of the gross allowance requirement. The corresponding values in per cent of the net use requirement are 90, 76, 64 and 61.

TABLE 62

AVAILABLE WATER SUPPLY AND ULTIMATE WATER REQUIREMENTS
SAN JOAQUIN RIVER BASIN

Section	Seasonal full natural run-off, in acre-feet				Seasonal water requirements, in acre-feet	
	40-year mean, 1889-1929	20-year mean, 1909-1929	10-year mean, 1919-1929	5-year mean, 1924-1929	Gross allowance	Net use
Upper San Joaquin Valley	3,651,200	3,128,300	2,527,400	2,355,700	7,296,000	7,296,000
Lower San Joaquin Valley* and foothill areas	*8,328,800	*7,031,300	*6,019,500	*5,781,300	6,030,000	3,656,000
San Joaquin Delta					2,414,000	2,414,000
Totals	11,980,000	10,159,600	8,546,900	8,137,000	15,740,000	13,366,000

* Includes run-off of San Joaquin River and delta tributaries.

Under present conditions of development, it has been definitely pointed out that there are many areas in the upper San Joaquin Valley which are overdrawing the water supplies locally available to them. The water supplies now utilized in the upper San Joaquin Valley comprise the run-off of the streams from the Chowchilla River south, excluding the San Joaquin River. With the present utilization of supplies from these sources, the amount of water available even in a series of wet years in some instances would be of no avail in relieving the water shortage situation. Some of the areas require water supplies far beyond those which are naturally available to them. In the lower San Joaquin Valley, it has been shown that the local water supplies furnished by the San Joaquin River and its east-side tributaries are generally adequate in amount and dependable in occurrence for the areas now under irrigation. However, in the San Joaquin Delta, the water supply now available thereto from the San Joaquin River and its tributaries comprises only such portions of the run-off of these streams in excess of the present net use in the entire lower San Joaquin Valley floor and adjacent foothills. This supply, together with supplies from the Sacramento River, in several recent years have been insufficient to meet the water requirements in the delta and the water in the delta channels has been rendered unfit for irrigation purposes in the summer and fall months by invasion of saline water from upper San Francisco Bay.

The full utilization of all of these available water supplies is not possible of accomplishment. The degree of utilization is limited by many factors, among which are: the availability of surface storage reservoir sites, the utilization of which involves evaporation losses; the availability of utilizable ground water reservoirs; the distance between sources of supply and areas of use, and consequent conveyance losses; and the geologic and topographic conditions which are controlling factors in the extent to which water applied in excess of net use can be recovered for reuse. As will be demonstrated in Chapter VII, it is physically feasible to utilize about 85 per cent of the run-off of the San Joaquin River Basin streams under conditions of ultimate development. This high degree of utilization requires proper coordination of all necessary physical works; namely, surface reservoirs, underground reservoirs, conveyance channels and other works for the diversion of return flows in stream channels for reuse. Therefore, it is obvious that the water supply of the San Joaquin River Basin falls far short of ultimate irrigation requirements and any plan for the ultimate irrigation development of the basin must be predicated on the importation of large volumes of water from an outside source of supply.

Source of Supplemental Supply.

It has been demonstrated in analyses presented in another report* that, by the utilization of the proposed ultimate physical works of the State Water Plan in the Sacramento River Basin including the Trinity River diversion, regulated supplies, without deficiency in amount and dependable in time, could have been made available in the principal streams during the dry period 1918–1929, to irrigate all of the net irrigable area in the Sacramento Valley, after allowing gross diversions for the irrigation of all of the irrigable foothill and mountain valley lands in the Sacramento River Basin. The analyses also show that there would have been a large surplus of water in every year, over and above all needs in the basin above the Sacramento-San Joaquin Delta.

Table 63 shows, for the Sacramento River Basin, the amounts of water contributed from the reservoirs and from unregulated run-off, the gross requirements for valley lands above the delta, the return flow from valley and from foothills not tributary to the reservoirs, and the remaining surpluses available in the delta in the maximum and minimum years and an average for all years during the 11-year period 1918–1929.

The total ultimate average annual requirement for the Sacramento-San Joaquin Delta, including salinity control, would amount to about 3,590,000 acre-feet. A portion of this would be contributed by water from the San Joaquin Valley streams. However, if the entire amount had been obtained from Sacramento Valley waters during the 11-year

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

period 1918–1929, there still would have been surpluses in the maximum and minimum years of 11,399,000 and 2,164,000 acre-feet, respectively, and an average annual surplus for the period of 6,702,000 acre-feet. The Sacramento River Basin is the only available practicable source of supply for exportation to the San Joaquin River Basin.

TABLE 63

SURPLUS WATER IN SACRAMENTO RIVER BASIN

Exclusive of Sacramento-San Joaquin Delta Requirements

Item	Amount of water, in acre-feet		
	Maximum year, 1927	Minimum year, 1924	Average annual, for period 1918–1929
Releases and spill from major reservoir units and unregulated run-off	19,837,000	10,608,000	15,141,000
Gross requirements for lands on Sacramento Valley floor	9,033,000	9,033,000	9,033,000
Surplus from releases and spill and unregulated run-off	10,804,000	1,575,000	6,108,000
Return water—from valley floor	3,843,000	3,843,000	3,843,000
Return water—from foothills not tributary to reservoirs	341,000	341,000	341,000
Total surplus available in delta	14,988,000	5,759,000	10,292,000

Ultimate Water Service Areas and Water Requirements Under State Water Plan in San Joaquin River Basin.

The ultimate development of the San Joaquin River Basin will require the importation of available surplus water supplies from the Sacramento River Basin. For the upper San Joaquin Valley, where supplies from outside sources will be required, the cost of such importation would be relatively high and in general would exceed that of develing local sources of supply. Therefore, it has been assumed that, under conditions of ultimate development, the maximum practicable utilization of all local sources of supply will be made and service will be justified only for the better lands. In evolving that portion of the State Water Plan pertaining to the furnishing of a water supply to the upper San Joaquin Valley, the area of service was taken to include only lands in Classes 1 and 2, and a small area of Class 3 land suitable for citrus development which could be irrigated by diversion from Tule River. Hydrographic divisions and zones of water service are delineated on Plate VI. There are 7000 acres of Class 2 land in Zone 1c and 22,000 acres of Class 1 land in Zone 1e which were not included in the areas of service. These lands are unfavorably situated topographically with respect to available water supply. The lands in Zone 1c are more than 200 feet higher in elevation than the canals which serve areas north of Kern River under the State Water Plan. The lands in Zone 1e lie at elevations higher than could be served by a lift of 350 feet above the proposed Kern River diversion canal around the southern end of the valley.

In the lower San Joaquin Valley, all classes of irrigable land have been included in estimating the required irrigation supply. This procedure was followed also in estimating the irrigation requirements for lands in the Sacramento River Basin. The service area and ultimate water requirements of the San Joaquin Delta have been discussed in Chapter V. The requirements of the Delta are to be met by storage development in the Sacramento River Basin. Plans for making this required supply available are discussed in other reports.* Table 64 sets forth, by hydrographic divisions, net service areas and seasonal water requirements of all lands to be supplied by the ultimate State Water Plan in the San Joaquin River Basin, excluding the San Joaquin Delta.

Although irrigation requirements have been the primary consideration in the study of the utilization of available supplies and the design of a system of physical works to effect such utilization, the requirements for domestic, municipal and industrial water supply, flood control, power development and navigation also have been considered in the formulation of that portion of the State Water Plan pertaining to the San Joaquin River Basin. Flood control and navigation features of the plan are discussed and presented in Chapters IX and X, respectively. The provisions for domestic, municipal and industrial water supply and power development features are presented with the discussions of the various units to which they are incidental.

TABLE 64

ULTIMATE WATER SERVICE AREAS AND WATER REQUIREMENTS UNDER STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, EXCLUDING SAN JOAQUIN DELTA BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions, see Plate VI

Hydrographic division	Net service area, in acres	Seasonal water requirements, in acre-feet					
		Gross allowance		Net allowance		Net use	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Upper San Joaquin Valley Floor							
1	791,000	1,582,000	2.0	1,582,000	2.0	1,582,000	2.0
2	566,000	1,132,000	2.0	1,132,000	2.0	1,132,000	2.0
3	270,000	540,000	2.0	540,000	2.0	540,000	2.0
4	830,000	1,660,000	2.0	1,660,000	2.0	1,660,000	2.0
5	260,000	520,000	2.0	520,000	2.0	520,000	2.0
5B	221,000	442,000	2.0	442,000	2.0	442,000	2.0
6	197,000	394,000	2.0	394,000	2.0	394,000	2.0
Totals	3,135,000	6,270,000	2.0	6,270,000	2.0	6,270,000	2.0
Lower San Joaquin Valley Floor							
7 South of Merced River	203,000	670,000	3.3	487,000	2.4	426,000	2.1
7 Lower west side pumping areas	62,000	124,000	2.0	112,000	1.8	99,000	1.6
7 West side rim lands	143,000	286,000	2.0	257,000	1.8	229,000	1.6
8	282,000	930,000	3.3	677,000	2.4	536,000	1.9
9	312,000	1,030,000	3.3	749,000	2.4	593,000	1.9
10	69,000	138,000	2.0	124,000	1.8	110,000	1.6
11	260,000	858,000	3.3	624,000	2.4	494,000	1.9
12	218,000	589,000	2.7	392,000	1.8	336,000	1.54
13	127,000	343,000	2.7	229,000	1.8	196,000	1.54
Totals	1,676,000	4,968,000	3.0	3,651,000	2.2	3,019,000	1.8
Foothills Areas							
8A	84,000	252,000	3.0	202,000	2.4	151,000	1.8
9A	62,000	186,000	3.0	149,000	2.4	112,000	1.8
11A (In Tuolumne watershed)	36,000	108,000	3.0	86,000	2.4	65,000	1.8
11A (In Stanislaus watershed)	37,000	93,000	2.5	56,000	1.5	55,000	1.5
12A	81,000	202,000	2.5	122,000	1.5	122,000	1.5
13A	39,000	98,000	2.5	59,000	1.5	58,000	1.5
Totals	339,000	939,000	2.8	674,000	2.0	563,000	1.7
Totals, San Joaquin River Basin, excluding San Joaquin Delta	5,150,000	12,177,000	---------	10,595,000	---------	9,852,000	---------

* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

Fundamental Elements of State Water Plan.

The basic objective of the State Water Plan is to provide and operate works for the conservation, development, control, utilization and distribution of the waters of the State so that all areas within the State, when completely developed, might have adequate water supplies for all uses and flood protection. Provision would be made for domestic, municipal, industrial, irrigation, mining and recreational water requirements, improvement of navigation on navigable streams, flood control, control of salinity and power development.

In the formulation of the plan, the following economic principles are recognized as fundamental:

1. It should be formulated with a long time viewpoint.
2. It should be a progressive development with the various units constructed only as necessity demands.
3. It should be in consonance with present rights and interests as far as practicable so as to result in the least possible interference with existing agencies and their operations.
4. The water requirements of all interests must be given consideration.
5. Accruing benefits must far outweigh the damages which might result from the execution of the plan.
6. The fullest practicable utilization of both local and imported waters should be made, particularly in areas of deficient water supply.
7. The initial units constructed for the rehabilitation of agriculture should now be extended only to developed areas of deficient local water supply.
8. Units of initial development should be so planned that they can be enlarged and extended at the minimum expense to allow for expansion as economics dictate and that they are in accord with an ultimate plan of development.
9. The plan should be so formulated and carried out that the greatest benefit will be obtained at the least cost.

The basic features included in the plan for the Great Central Valley are storage reservoirs, both surface and underground, and natural and artificial conveyance channels. Surface reservoirs would be constructed on the major streams and operated to equalize the erratic run-off in the interest of all desired purposes and uses. Hydroelectric power plants would be installed at those dams where such development would be justified in order to assist in defraying the cost of all features of the plan. Underground reservoirs, where available, would be utilized to the fullest practicable extent. Conveyance channels, both natural and artificial, would transport water supplies from areas having a surplus to areas of deficiency.

The proposed plan provides only the major units for storage, conveyance and utilization. In addition to these major units of the State Water Plan, many storage reservoirs, distribution canals and laterals, pumping plants and other works, both already constructed and to be constructed, would be required and utilized to provide for the full practicable conservation, regulation, distribution and utilization of the water resources.

Major Units for Ultimate Development in San Joaquin River Basin.

The physical works of that portion of the State Water Plan for the ultimate development of the San Joaquin River Basin are designed to provide for:

1. The fullest practicable utilization, through the combined means of surface and ground water storage, of all water supplies tributary to the San Joaquin River Basin.
2. The storage and regulation of main San Joaquin River water and its diversion to and utilization in the area on the east side of the upper San Joaquin Valley.
3. The conveyance and distribution of surplus Sacramento River Basin water, made available by storage and regulation with the major units of the State Water Plan for the Sacramento River Basin, to provide for that portion of the water requirements of the San Joaquin Valley which can not be met by the fullest practicable utilization of local water supplies.
4. The substitution, for the main San Joaquin River water now used on lands north of Mendota which the plan proposes to divert to the east side of the upper San Joaquin Valley, of imported Sacramento River Basin water and return flow waters of the lower San Joaquin River tributaries.
5. The conveyance and distribution of imported Sacramento River Basin water and return flow waters of the lower San Joaquin River tributaries to undeveloped lands along the west side of the San Joaquin Valley, north and south of Mendota.

In the remainder of this chapter, the major units of the plan for the San Joaquin River Basin, designed in accord with the foregoing provisions, are discussed under the following headings:

1. Surface storage reservoirs.
2. Underground reservoirs.
3. Conveyance units.

The location of these units are shown on Plate XXVI "Major Units of State Plan for Development of Water Resources of California."

The major units of the State Water Plan in the Sacramento River Basin which, by storage and regulation, would provide surplus waters in excess of the full requirements of the Sacramento River Basin for importation to the San Joaquin Valley, are described in detail in other reports.* They comprise ten surface storage reservoirs on the Sacramento River and its tributaries and one on the Trinity River with a diversion conduit into the Sacramento River Basin, with an aggregate storage capacity for the eleven reservoirs of 12,687,000 acre-feet. Detailed data on the operation and accomplishments of these reservoirs, particularly as to the amounts of surplus water made available for importation to the San Joaquin Valley, are presented in the reports cited and are summarized in Chapter VII. Since the ultimate development of the San Joaquin River Basin is materially dependent upon the furnishing of substantial amounts of water from the Sacramento River

* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

Basin, the major units of the State Water Plan for the Sacramento River Basin, as described in detail in the reports cited, are considered to be an essential part of the plan for the San Joaquin River Basin. The units in the two basins are interrelated and interdependent in their operations and accomplishments and taken together constitute a unified plan of development for the entire Great Central Valley Basin.

In addition to the major units of the State Water Plan for the Great Central Valley proper and combined therewith as a part of the Great Central Valley Project, provision is made for furnishing the immediately adjacent San Francisco Bay Basin with required supplemental water supplies from Great Central Valley sources by conveyance units extending from the Sacramento-San Joaquin Delta channels into the San Francisco Bay region. Conveyance units for this purpose are described in another report,* and other conduits either could be or have been provided. The city of San Francisco has nearly completed a conduit from the Hetch Hetchy watershed on the Tuolumne River to provide a municipal and domestic supply for San Francisco and adjacent territories, which will have an ultimate capacity of 400,000,000 gallons daily. The East Bay Municipal Utility District has already completed and is operating a conduit bringing in water from the Mokelumne River to the cities in the East Bay territory for municipal and domestic supply. The proposed ultimate capacity of this conduit is 200,000,000 gallons per day. Allowance has been made in the studies of water supply and utilization in the Sacramento and San Joaquin River basins for the ultimate exportation of these amounts of water to these San Francisco Bay metropolitan areas.

SURFACE STORAGE RESERVOIRS

The major surface storage units of the ultimate State Water Plan for the San Joaquin River Basin are thirteen in number, located generally immediately above the rim of the valley in the lower foothills. Salient physical data on these reservoir units, having an aggregate storage capacity of 5,130,000 acre-feet, are presented in Table 65.

The methods of operation of these reservoirs, the water yields obtained and the accomplishments effected are presented with the discussion of each reservoir in this chapter and further elucidated in Chapter VII. In selecting the locations and sizes of the surface storage units, careful consideration and study were given to the accomplishments sought or desired and the physical and economic limits of development. The objective was to obtain the maximum resulting benefits at minimum costs. Analyses were made of reservoirs at various sites on each major stream to determine the most feasible location and economic capacity for the purposes to be served. This procedure involved the preparation of cost estimates, both capital and annual, and analyses of water yield for each site and capacity investigated. For those reservoirs where hydroelectric power production appeared advantageous the economic installations of the power plants also were carefully considered.

The estimates of capital cost were prepared in considerable detail, based on prices of materials and labor as of 1929 and 1930. Unit prices

* Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

Basin, the major units of the State Water Plan for the Sacramento River Basin, as described in detail in the reports cited, are considered to be an essential part of the plan for the San Joaquin River Basin. The units in the two basins are interrelated and interdependent in their operations and accomplishments and taken together constitute a unified plan of development for the entire Great Central Valley Basin.

In addition to the major units of the State Water Plan for the Great Central Valley proper and combined therewith as a part of the Great Central Valley Project, provision is made for furnishing the immediately adjacent San Francisco Bay Basin with required supplemental water supplies from Great Central Valley sources by conveyance units extending from the Sacramento-San Joaquin Delta channels into the San Francisco Bay region. Conveyance units for this purpose are described in another report,* and other conduits either could be or have been provided. The city of San Francisco has nearly completed a conduit from the Hetch Hetchy watershed on the Tuolumne River to provide a municipal and domestic supply for San Francisco and adjacent territories, which will have an ultimate capacity of 400,000,000 gallons daily. The East Bay Municipal Utility District has already completed and is operating a conduit bringing in water from the Mokelumne River to the cities in the East Bay territory for municipal and domestic supply. The proposed ultimate capacity of this conduit is 200,000,000 gallons per day. Allowance has been made in the studies of water supply and utilization in the Sacramento and San Joaquin River basins for the ultimate exportation of these amounts of water to these San Francisco Bay metropolitan areas.

SURFACE STORAGE RESERVOIRS

The major surface storage units of the ultimate State Water Plan for the San Joaquin River Basin are thirteen in number, located generally immediately above the rim of the valley in the lower foothills. Salient physical data on these reservoir units, having an aggregate storage capacity of 5,130,000 acre-feet, are presented in Table 65.

The methods of operation of these reservoirs, the water yields obtained and the accomplishments effected are presented with the discussion of each reservoir in this chapter and further elucidated in Chapter VII. In selecting the locations and sizes of the surface storage units, careful consideration and study were given to the accomplishments sought or desired and the physical and economic limits of development. The objective was to obtain the maximum resulting benefits at minimum costs. Analyses were made of reservoirs at various sites on each major stream to determine the most feasible location and economic capacity for the purposes to be served. This procedure involved the preparation of cost estimates, both capital and annual, and analyses of water yield for each site and capacity investigated. For those reservoirs where hydroelectric power production appeared advantageous the economic installations of the power plants also were carefully considered.

The estimates of capital cost were prepared in considerable detail, based on prices of materials and labor as of 1929 and 1930. Unit prices

* Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

MAJOR UNITS OF STATE PLAN
FOR
DEVELOPMENT OF WATER RESOURCES
OF
CALIFORNIA

TABLE 65

ULTIMATE MAJOR SURFACE STORAGE UNITS OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Reservoir	Stream	Tributary drainage area, in square miles	Average seasonal ultimate net run-off for 40-year period 1889-1929, in acre feet	Height of main dam, in feet	Capacity of reservoir, in acre-feet
Nashville	Cosumnes River	435	290 000	270	281,000
Ione	Dry Creek	[1]270	[2]348,700	120	610,000
Pardee (constructed)	Mokelumne River	575	820,000	343	222,000
Valley Springs	Calaveras River	363	189,000	200	325,000
Melones	Stanislaus River	900	1,239,000	460	1,090,000
Don Pedro	Tuolumne River	1,536	1,634,000	455	1,000,000
Exchequer (constructed)	Merced River	1,034	989,000	307	279,000
Buchanan	Chowchilla River	238	70,900	147	84,000
Windy Gap	Fresno River	102	55,200	206	62,000
Friant	San Joaquin River	1,631	1,993,000	252	[3]400,000
Pine Flat	Kings River	1,544	1,889,000	274	400,000
Pleasant Valley	Tule River	[4]264	99,700	125	39,000
Isabella	Kern River	2,080	714,000	190	338,000
Total reservoir capacity					5,130,000

[1] Area in Dry Creek Basin, only.
[2] Includes 280,000 acre-feet of Mokelumne River water spilled from Pardee Reservoir.
[3] Effective capacity 270,000 acre-feet.
[4] Area above Pleasant Valley site, only.

for each reservoir were selected after a study of physical conditions at each dam site and available information on similar projects with comparable conditions. In fixing excavation prices for each dam, a field examination and studies of geological reports and information developed by subsurface explorations were made. Field examinations also were made in the vicinities of the dam sites to determine the nearest and best sources of materials for concrete aggregates and earth fill embankments. This information was used in fixing unit prices for the dams. Transportation facilities available to each dam site were investigated. Analyses were made of the cost of delivering construction materials to the sites, both by railroad and motor truck. The unit prices used for the principal items of base cost for reservoirs are set forth in Table 66. Costs given are for materials in place. They do not include any amounts for administration, engineering and contingencies, or for construction roads and railroads, camps and other miscellaneous items which have been estimated separately for each reservoir in cost estimates thereof hereafter presented. There have been added to the base cost in each estimate, 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction, based on a rate of 4.5 per cent per annum. The total amount of interest was computed on a basis of financing each six months work at the beginning thereof and compounding the interest to the end of the construction period.

The unit price used in estimating the costs of power plants at dam sites, including penstocks, outlets, control works, by-passes and all other appurtenances is $50 per kilovolt ampere for all plants except Melones. The length of tunnel at the latter reservoir necessitated an increase in unit cost to $60 per kilovolt ampere. These prices include overhead and interest during construction.

TABLE 66

SUMMARY OF UNIT PRICES USED IN COST ESTIMATES OF RESERVOIRS

Item	Unit	Nashville Reservoir	Ione Reservoir	Valley Springs Reservoir	Melones Reservoir	Don Pedro Reservoir	Buchanan Reservoir	Windy Gap Reservoir	Friant Reservoir	Pine Flat Reservoir	Pleasant Valley Reservoir	Isabella Reservoir
Excavation, earth	Cubic yard	----------	$0 35-$0 75	$1 00	----------	----------	----------	$1 00	$1 00	----------	$0 75-$2 00 wet-3 00	$0 50
Excavation, dry rock	Cubic yard	$3 00	2 00	3 00	$3 00	$3 00	$4 50	3 50	3 00	$3 50	----------	3 00
Excavation, wet rock	Cubic yard	5 00	----------	5 00	5 00	5 00	----------	5 00	5 00	5 00	----------	5 00
Concrete, mass	Cubic yard	7 85	----------	6 30	7 90	7 20	8 25	8 25	6 30	6 50	----------	9 00
Earthfill embankment	Cubic yard	----------	75	----------	----------	----------	----------	----------	----------	----------	75	75
Reinforced concrete—												
Spillway piers	Cubic yard	18 00	20 00	18 00	18 00	18 00	18 00	18 00	17 00	18 00	----------	19 00
Roadway over spillway	Cubic yard	30 00	----------	30 00	30 00	45 00	30 00	30 00	30 00	30 00	----------	30 00
Parapets	Cubic yard	21 00	----------	21 00	21 00	21 00	21 00	21 00	20 00	20 00	----------	22 00
Spillway channel	Cubic yard	----------	11 20-15 00	8 00-14 00	----------	15 00	9 00	9 00	8 00	10 00	10 00-15 00	10 00
Inlet structures	Cubic yard	21 00	15 00-28 00	21 00	21 00	21 00	21 00	21 00	20 00	20 00	25 00	27 00
Cut-off walls	Cubic yard	----------	15 00-16 50	----------	----------	----------	----------	----------	----------	----------	15 00-18 00	18 00
Slope paving	Cubic yard	----------	15 00	----------	----------	----------	----------	----------	----------	----------	15 00	16 00
Outlet conduits	Cubic yard	----------	16 50	----------	----------	----------	----------	----------	----------	----------	15 00	27 00
Drilling grout holes and drainage wells	Linear foot	3 00	----------	3 00	3 00	3 00	3 00	3 00	3 00	3 00	----------	3 00
Pressure grouting	Cubic yard	70 00	----------	70 00	70 00	70 00	70 00	70 00	70 00	70 00	----------	70 00
Vertical drains in dam	Linear foot	50	----------	50	50	50	50	50	50	50	----------	50
Steel in trash racks	Pound	10	10	10	10	10	10	10	10	10	10	11
Reinforcing steel	Pound	06	05	06	06	06	06	06	06	06	05	0 06-0 07
Riveted steel pipe outlets through dam	Pound	10	----------	10	10	10	10	10	10	10	----------	11
Caterpillar type sluice gates	Pound	22	22	22	----------	----------	----------	----------	22	----------	22	23
Slide gates	Pound	13	----------	13	13	13	13	13	13	13	----------	14
Needle valves	Pound	28	----------	28	28	28	28	28	28	28	----------	29
Segmental steel drum gates	Pound	10	10	10	10	10	11	11	10	10	----------	12
Contraction seals	Linear foot	2 25	----------	2 25	2 25	2 25	2 25	2 25	2 25	2 25	----------	2 25

The estimated annual cost for each reservoir unit comprises interest and amortization on capital investment, and depreciation, operation and maintenance of physical works. The bases used in estimating the annual costs are as follows:

Interest on capital investment, in per cent	4.5
Amortization of capital investment (40-year bonds on 4 per cent sinking fund basis) in per cent of capital cost	1.05
Depreciation—	
Dam and reservoir, in per cent of capital cost	0.3
Power plant (40-year sinking fund basis at 4 per cent) in per cent of capital cost	1.05
Operating expense and maintenance—	
Dam and reservoir, in per cent of capital cost	0.15
Power plant	$10,000 plus $0.65 per kilovolt ampere of installed capacity.

Nashville Reservoir on Cosumnes River.

The dam site for the Nashville reservoir on the Cosumnes River is located just below the confluence of the main river and Big Indian Creek in the northwest quarter of Section 14, Township 8 North, Range 10 East, M.D.B. and M., about five miles northerly from the town of Plymouth, in Amador and El Dorado counties. The reservoir would be of trifurcated shape, extending up the main river, North Fork and Big Indian Creek.

Two lower reservoir sites—one at Wisconsin Bar and the other at Michigan Bar, were investigated, but it was found that their potential capacities were inadequate to give proper regulation. The Nashville site was found to be the most favorable although it has a somewhat smaller watershed. The bulk of the run-off (about 93 per cent), however, originates above the Nashville site.

The drainage areas on the Cosumnes River watershed, above Nashville dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	84 square miles
Area between elevations 2500 and 5000 feet	212 square miles
Area below elevation 2500 feet	139 square miles
Total area above Nashville dam site	435 square miles

Present Development on Cosumnes River—Development both above and below the Nashville site is relatively small. No power plants have been constructed. Several ditches originally constructed for mining purposes divert water above the Nashville site for irrigation and domestic purposes. The total quantity of water diverted is small in comparison with the run-off of the watershed. The Enterprise Ditch, which heads on the Middle Fork, diverts water also from the South Fork and from a number of minor streams which it crosses on its way toward the town of Plymouth. The Crawford Ditch diverts water from Camp Creek below its junction with Sly Park Creek and serves certain scattered irrigated areas on the ridge between Webber Creek and the Cosumnes River, in the vicinity of El Dorado. The North Fork Extension Ditch diverts water from the North Fork just below its junction with Steeley Fork and supplements the supply of Crawford Ditch.

On the lower reaches of the river, certain riparian owners have irrigated farm lands for many years. Diversions are usually made by means of low dams. Also, lands adjacent to the river are flooded during high river stages. The Cosumnes Irrigation Association, a private company, has constructed diversion works about 1.5 miles below Michigan Bar and also a ditch running some six miles west, for the irrigation of certain riparian lands, about 1000 acres of which have been irrigated up to the present time. Small pumping plants are used at many points during the summer months. The total diversion capacity of riparian owners is estimated as 300 second-feet. No information is available as to quantities actually diverted.

Water Supply—The water supply considered as available for regulation would comprise the run-off of the Cosumnes River above the Nashville dam site after subtracting the gross diversions for certain lands in the American River Basin and all those to be ultimately irrigated above the reservoir, and adding the estimated return flow from the diversions within the Cosumnes River watershed above the reservoir. The net reservoir evaporation loss is estimated at 3.5 feet depth per season on the reservoir surface. For the 40-year period 1889–1929, it is estimated that the average seasonal ultimate net run-off would have been 290,000 acre-feet.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 2000 feet, was prepared by Stephen E. Kieffer from a survey made by him in 1925. A plane table survey of the dam site, scale one inch equals 200 feet, was made by the State in the same year. Table 67 sets forth areas and capacities for various heights of dam.

TABLE 67

AREAS AND CAPACITIES OF NASHVILLE RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
25	775	20	200
50	800	60	1,200
75	825	190	4,400
100	850	390	11,500
125	875	640	24,000
150	900	950	44,000
175	925	1,320	72,600
200	950	1,740	110,000
225	975	2,210	159,000
250	1,000	2,730	222,000
270	1,020	3,180	281,000
275	1,025	3,300	297,000
300	1,050	3,890	387,000
325	1,075	4,510	492,000
350	1,100	5,220	613,000

Based upon the ultimate net run-off of the Cosumnes River for the period 1918–1929, the studies show that the selected reservoir capacity of 281,000 acre-feet would have regulated the flow without waste. The reservoir would have a flow line elevation of 1020 feet and a submerged area of 3180 acres. It would back water up the North, Middle and South forks, and Big Indian Creek, and would be some 10 miles in length and one-half mile in average width. The reservoir area consists mostly of mountain land covered with brush and scattering timber of no commercial value. It is used principally for grazing purposes. Nashville, the remains of an old mining town, would be flooded. The value of the buildings is small. Several old gold mines and mining claims are within the proposed reservoir area. None are active with the possible exception of the Montezuma Mine. The Mother

Lode Highway from El Dorado to Plymouth traverses the reservoir site and the road is paralleled by a power line (single circuit, 60,000-volt, wood pole). Relocation of ten miles of highway and nine miles of power line would be necessary.

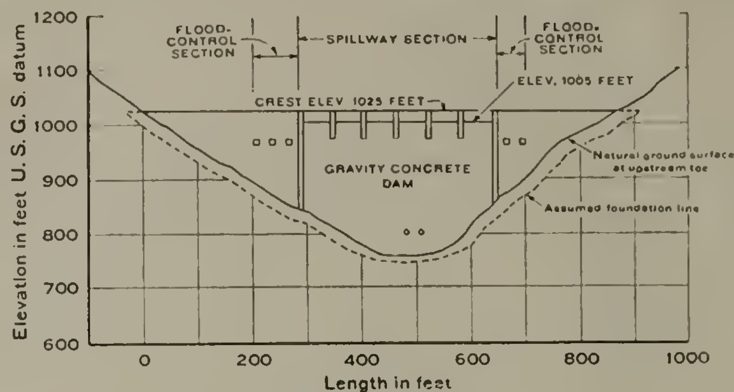
The water supply which could be made available from Nashville Reservoir is not sufficient for the requirements of the lands to be served in the service area (Hydrographic Division 13) of the Cosumnes River. It is proposed to obtain required supplemental supplies from the American River. Accordingly, under the ultimate State Water Plan, Nashville Reservoir would be operated coordinately with the supply imported from the American River. With such coordinate operation, the mean annual irrigation yield of Nashville Reservoir, for the 11-year period 1918–1929, would have been 163,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

Dam Site—The dam site is a narrow "V" shaped gorge. A geological examination (see Appendix C) shows it to be suitable for a high concrete structure. Solid bed rock (diabase) is exposed in the stream bed. The same formation follows a cliff profile to 125 feet above stream bed. On the higher slopes there is a considerable overburden of earth and jointing which has weakened the massive rock near the surface so that large blocks have been loosened from the mass. No borings or test pits have been made at the site, but from field examination, it is estimated that the removal of surface and underlying loose blocks would necessitate an average depth of stripping of 20 feet on the right abutment and 25 feet on the left. In the stream bed, which consists of fresh bedrock with tight joints, an average stripping depth of ten feet would be necessary to produce an even surface and properly key the structure.

PLATE XXVII

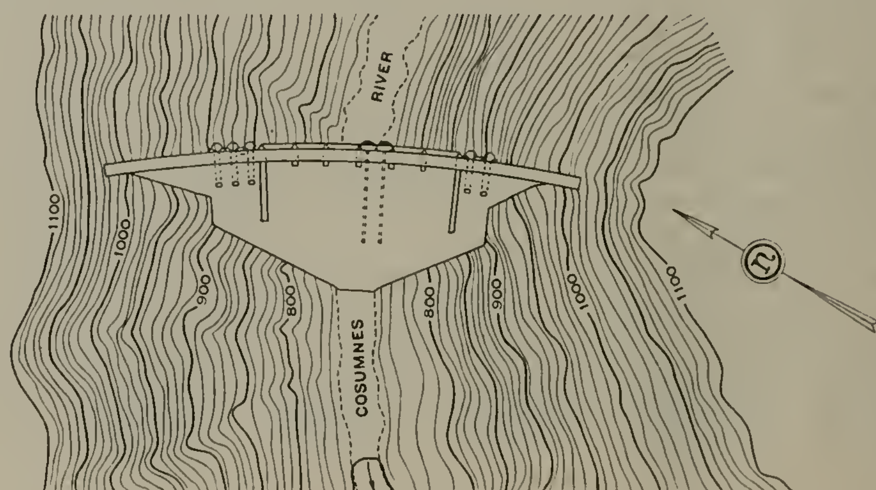
NASHVILLE DAM SITE ON COSUMNES RIVER

PLATE XXVIII



PROFILE OF DAM

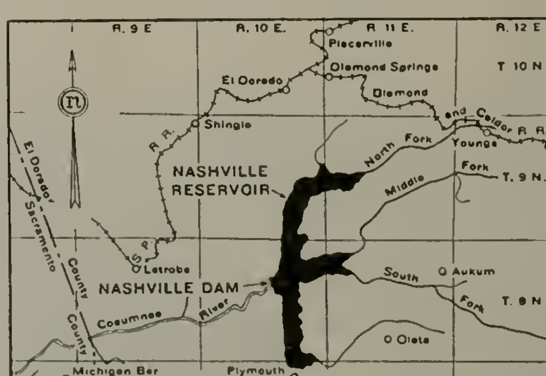
LOOKING UPSTREAM



GENERAL PLAN OF DAM

FEET

0 200 400



LOCATION MAP

SCALE OF MILES

0 4 8

NASHVILLE RESERVOIR

ON

COSUMNES RIVER

Dam and Appurtenances—The topography of the dam site and general layout of the dam and appurtenances required are shown on Plate XXVIII, "Nashville Reservoir on Cosumnes River." The height of the proposed dam is 270 feet above stream bed, including a five-foot freeboard. It is of the gravity-concrete type slightly curved to fit the topography, and has an overflow type of spillway in its center of 60,000 cubic feet per second capacity, controlled by six steel drum gates 50 feet long by 15 feet high. Reserve storage space of 56,000 acre-feet would be used for flood control. This would require a maximum drawdown of 20 feet, and would result in a regulated flow, exceeded once in one hundred years on the average, of 15,000 second-feet. For the purpose of flood regulation, the plans provide for five ten-foot by ten-foot openings through the dam, located at elevation 975 feet and controlled by gates of the caterpillar type at the upstream face of the dam. Two 48-inch diameter pipes with a discharging capacity of 1200 second feet, when operating under a minimum head of 50 feet, are provided for release of irrigation supplies. The inlet ends of these irrigation outlets are located at elevation 780 feet, and are controlled by two 48-inch needle valves and two four-foot emergency slide gates. No hydroelectric power installation is contemplated at this site.

Cost of Nashville Reservoir—The capital and annual costs of Nashville Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 68.

TABLE 68

COST OF NASHVILLE RESERVOIR

Height of dam, 270 feet. Capacity of reservoir, 281,000 acre-feet.
Capacity of spillway, 60,000 second-feet.
Capacity of irrigation outlets, 1,200 second-feet.
Capacity of flood control outlets, 15,000 second-feet.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		760,000
Excavation for dam, 97,000 cubic yards at $3.00 to $5.00	$314,000	
Mass concrete, 465,000 cubic yards at $7.85	3,650,000	
Reinforced concrete, 2,000 cubic yards at $18.00 to $30.00	45,000	
Spillway gates	120,000	
Irrigation outlets and sluiceways	54,000	
Flood control outlets	40,000	
Drilling, grouting, drains and contraction seals	50,000	
		4,273,000
Miscellaneous		472,000
Subtotal, dam and reservoir		$5,535,000
Administration and engineering, at 10 per cent		553,000
Contingencies at 15 per cent		830,000
Interest during construction, based on an interest rate of 4.5 per annum		482,000
Total capital cost of dam and reservoir		$7,400,000
Total annual cost of dam and reservoir		$441,000

Ione Reservoir on Dry Creek, a Tributary of Mokelumne River.

The main dam site for the Ione or Arroyo Seco Reservoir on Dry Creek, a tributary of the Mokelumne River, is located in the Arroyo Seco Ranch near what would be the west line of sections 7 and 18, Township 5 North, Range 9 East, M.D.B. and M., if the rancho were sectionized, and in Sacramento and San Joaquin counties about one mile west of the Amador County line. Two auxiliary dam sites are located in saddles northerly from the main site.

The Dry Creek basin, situated between the Cosumnes watershed on the north and the lower Mokelumne on the south, drains the lower slopes and foothills of the Sierra Nevada. It comprises an area of about 270 square miles above the dam site and rises to a maximum elevation of about 4300 feet. The total length of the watershed above the dam site is about 33 miles and the maximum width is about thirteen miles. The reservoir site is so situated that, in addition to the run-off naturally tributary from the Dry Creek basin, excess waters of the Mokelumne River after Pardee Reservoir has filled could be diverted into Ione Reservoir through the constructed Jackson Creek spillway located on the ridge between the two watersheds. As such water spilled from the Pardee Reservoir would occur in wet years only, cyclic storage would be necessary for its utilization.

Water Supply—The water supply considered available for regulation at this site would comprise the run-off of Dry Creek above the Ione Dam site less the net diversions for lands to be irrigated ultimately above the reservoir, and the excess Mokelumne River water spilled from Pardee Reservoir. The net reservoir evaporation loss is estimated as four feet in depth per season on the reservoir surface. The average seasonal ultimate net run-off, which would have been available for regulation at this site for the 40-year period 1889–1929, is 68,700 acre-feet, excluding spill from Pardee Reservoir. In addition, water spilled from Pardee Reservoir would have been available for regulation, amounting to 280,000 acre-feet, average seasonal for the 40-year period.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 2000 feet, and one of the main dam site, scale one inch equals 200 feet, were prepared from surveys made in 1925 by Stephen E. Kieffer. The State made surveys and prepared maps of the auxiliary dam sites in the same year. Table 69 sets forth areas and capacities for various heights of dam.

TABLE 69

AREAS AND CAPACITIES OF IONE RESERVOIR

Height of dam, in feet (10-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
40	190	1,400	20,000
60	210	3,700	75,000
80	230	6,800	181,000
100	250	10,700	360,000
120	270	14,800	610,000
140	290	18,700	930,000

The capacity selected for the reservoir, 610,000 acre-feet, is the amount of storage that would have been required to regulate without waste the ultimate net run-off of Dry Creek and the additional water spilled from Pardee Reservoir for the 11-year period, 1918–1929. This reservoir, with a flow line elevation of 270 feet, would back water up Jackson and Dry creeks about eight miles. It would have an average width of about four miles and a surface area of 14,800 acres.

The lands which would be included in the reservoir are mostly agricultural and range in quality from poor pasture land to that which is suitable for orchards. Several roads cross the reservoir site and would require relocation. The main road from Clements to Ione has an oiled or asphalt surface. The construction of 10 miles of new roads, 18 miles of reconstructed road and one highway bridge about 100 feet in length would be required if the dam were constructed. The Ione Branch of the Southern Pacific Railroad would be flooded for a portion of its length and the construction of 4.5 miles of new roadbed, together with three bridges having an aggregate length of 300 feet, would be required for its relocation.

Under the ultimate State Water Plan, Ione Reservoir would be operated coordinately with Pardee and Valley Springs reservoirs, on the Mokelumne and Calaveras rivers, respectively, together with imported supplies from the American River to furnish the water requirements of the lands to be served in hydrographic divisions 12 and 12A. With such coordinate operation, the mean annual irrigation yield from Ione Reservoir for the 11-year period, 1918–1929, would have been 150,000 acre-feet, including Mokelumne River water obtained by regulation of spill averaging 92,500 acre-feet annually, from Pardee Reservoir. This spill would have been the supply contributed from Mokelumne River after operating the Pardee Reservoir to yield a municipal supply of 200,000,000 gallons per day and an average annual irrigation supply of 294,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

Dam Site—The dam site is a relatively wide "U" shaped gap cut by the stream through a long rounded ridge. A geological examination of the site (See Appendix C) shows the formation to be sedimentary, consisting of nearly horizontally stratified fine to coarse grained tuffaceous sandstone beds, interbedded with siliceous shale members and conglomerate. The stream bed has an alluvial covering with an average thickness of 35 feet. The formation is considered inadequate to support a masonry dam but entirely satisfactory for an earth fill dam. The auxiliary dam sites are in saddles just northerly from the main site and the formations are of the same rock series as the upper 50 feet of the main site. Stripping might be limited to the removal of the top soil and vegetation only. A cut-off for the dam would be keyed into the rock which, though porous to a certain degree, is believed from available information to be sufficiently fine textured in the sandstone and conglomerate matrix to be practically impervious.

Dams and Appurtenances—The topography of the dam site and general layout of the proposed dam, auxiliary dams and appurtenances are shown on Plate XXX, "Ione Reservoir on Dry Creek." The main dam is an earth fill section with a length along the crest of 3750 feet and a maximum height of 120 feet. There are two auxiliary dams, designated on the plans as Dam "A" and Dam "B." Dam "A" has a crest length of 2580 feet and a maximum height of 40 feet. Dam "B" is 300 feet long with a maximum height of 15 feet. All three dams have a theoretical cross section with a crest width of 20 feet and upstream and downstream slopes of 3 to 1 and 2½ to 1 respectively. The spillway is located on the left abutment of auxiliary Dam "A".

This is a concrete structure consisting partly of a section controlled by five steel drum gates 15 feet high by 45 feet long and partly of an uncontrolled overpour weir section. The capacity of the spillway is 42,000 second-feet with a reservoir level at elevation 270 feet or 10 feet below the crest level of the dams.

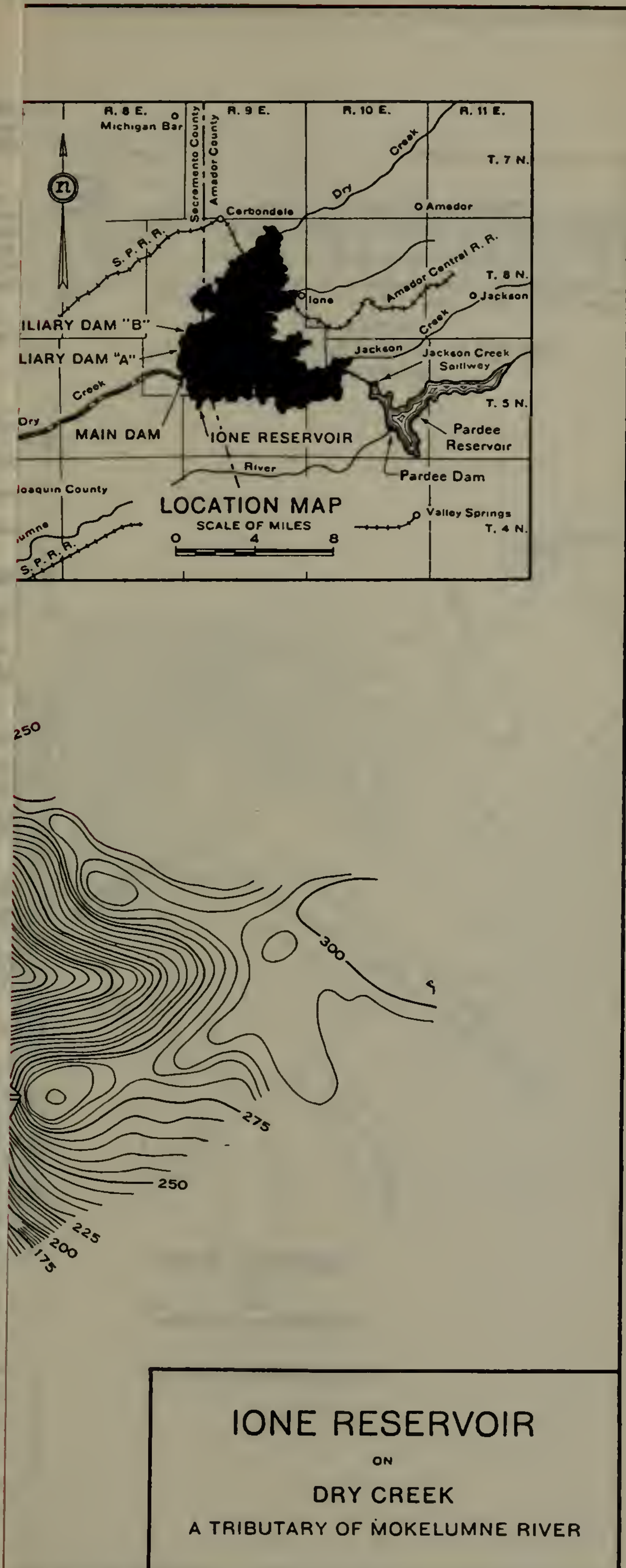
A reinforced concrete conduit is provided under the right abutment of the main dam for the release of irrigation supplies. The capacity of this conduit is 750 second-feet under a minimum head of eight feet. The conduit, 10 feet in diameter and 700 feet in length, is controlled by two, 5 feet by 5 feet, caterpillar type gates on the outer

PLATE XXIX

IONE DAM SITE ON DRY CREEK, A TRIBUTARY OF MOKELUMNE RIVER

side of a reinforced concrete gate tower, and one, 7 feet by 7 feet, emergency gate of the same type on the inside of the tower. Reserve storage space of 121,000 acre-feet requiring a maximum drawdown of 9 feet would be used for the control of floods, including flood diversions through the Jackson Creek Spillway from the Pardee Reservoir. This would result in a regulated flow of 5000 second-feet exceeded once in 100 years on the average. Flood control regulation is secured through the operation of the drum gates in the spillway section, which have a capacity of twice the regulated flow of 5000 second-feet with the reservoir level at elevation 261 feet. No hydroelectric power development is proposed at this site.

Cost of Ione Reservoir—The capital and annual costs of Ione Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 70.



IONE RESERVOIR
ON
DRY CREEK
A TRIBUTARY OF MOKELUMNE RIVER

This is a concrete structure consisting partly of a section controlled by five steel drum gates 15 feet high by 45 feet long and partly of an uncontrolled overpour weir section. The capacity of the spillway is 42,000 second-feet with a reservoir level at elevation 270 feet or 10 feet below the crest level of the dams.

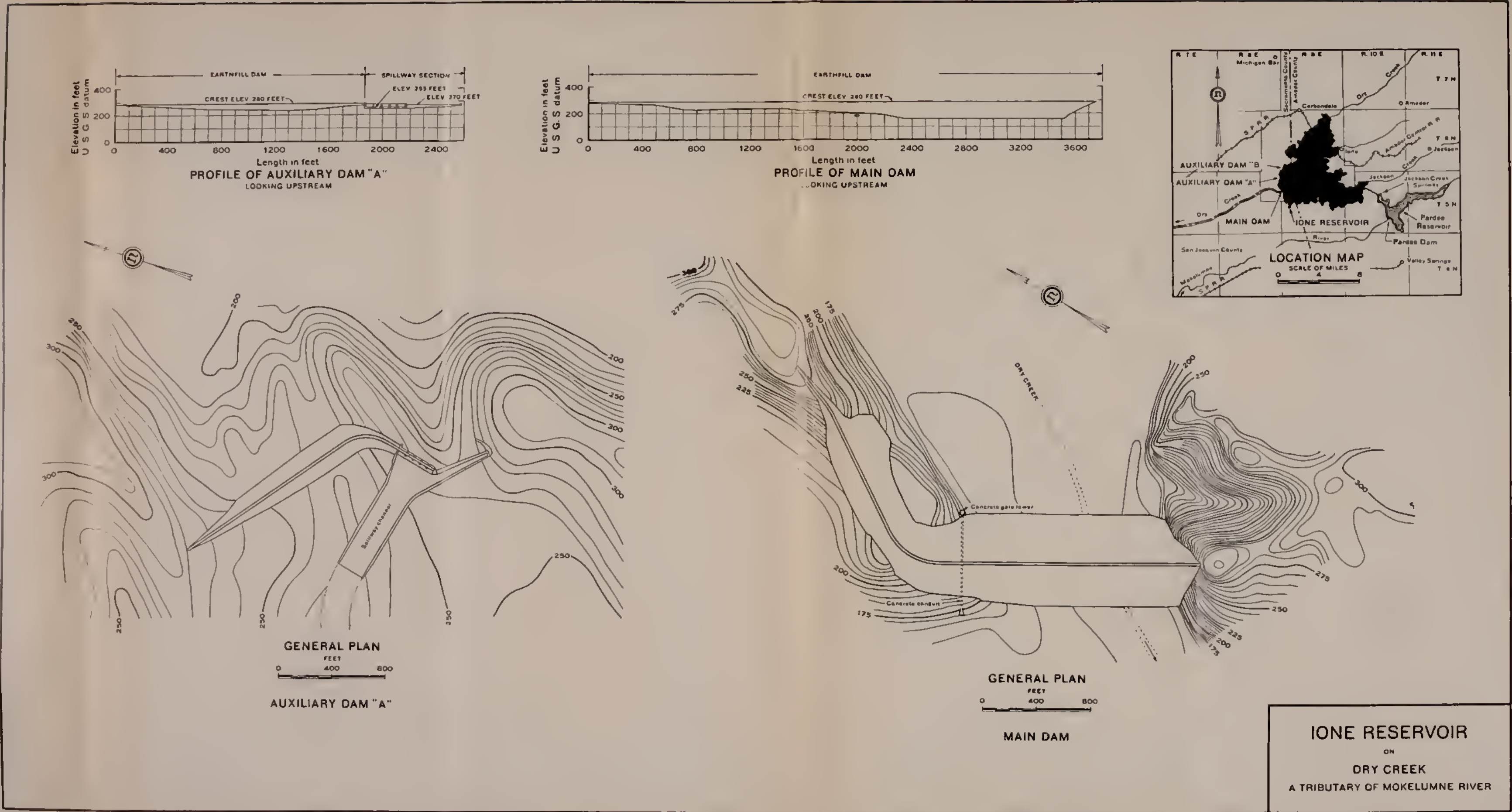
A reinforced concrete conduit is provided under the right abutment of the main dam for the release of irrigation supplies. The capacity of this conduit is 750 second-feet under a minimum head of eight feet. The conduit, 10 feet in diameter and 700 feet in length, is controlled by two, 5 feet by 5 feet, caterpillar type gates on the outer

PLATE XXIX

IONE DAM SITE ON DRY CREEK, A TRIBUTARY OF MOKELUMNE RIVER

side of a reinforced concrete gate tower, and one, 7 feet by 7 feet, emergency gate of the same type on the inside of the tower. Reserve storage space of 121,000 acre-feet requiring a maximum drawdown of 9 feet would be used for the control of floods, including flood diversions through the Jackson Creek Spillway from the Pardee Reservoir. This would result in a regulated flow of 5000 second-feet exceeded once in 100 years on the average. Flood control regulation is secured through the operation of the drum gates in the spillway section, which have a capacity of twice the regulated flow of 5000 second-feet with the reservoir level at elevation 261 feet. No hydroelectric power development is proposed at this site.

Cost of Ione Reservoir—The capital and annual costs of Ione Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 70.



IONE RESERVOIR

ON

DRY CREEK

A TRIBUTARY OF MOKELUMNE RIVER


GENERAL PLAN

TABLE 70

COST OF IONE RESERVOIR

Height of dam, 120 feet. Capacity of reservoir, 610,000 acre-feet.
Capacity of spillway, 42,000 second-feet.
Capacity of irrigation outlet, 750 second-feet.

Exploration		$10,000
Diversion of river during construction		60,000
Lands and improvements flooded and clearing		2,528,000
Excavation for dams, 152,000 cubic yards at $0.35 to $2.00	$103,000	
Earth fill in dams, 3,167,000 cubic yards at $0.75	2,375,000	
Reinforced concrete face, 21,000 cubic yards at $15.00	315,000	
Miscellaneous reinforced concrete cut-off walls, 6,000 cubic yards at $15.00 to $28.00	95,000	
Spillway gates	93,000	
Spillway channel	543,000	
Irrigation outlet tower, conduit and gates	70,000	
		3,594,000
Miscellaneous		168,000
Subtotal, dam and reservoir		$6,360,000
Administration and engineering at 10 per cent		636,000
Contingencies at 15 per cent		954,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		650,000
Total capital cost of dam and reservoir		$8,600,000
Total annual cost of dam and reservoir		$517,000

Pardee Reservoir on Mokelumne River.

The Pardee Reservoir is located on the Mokelumne River in Amador and Calaveras counties in Township 5 North, Ranges 10 and 11 East, M.D.B. and M., about five miles northerly from the town of Valley Springs. It is already developed by the East Bay Municipal Utility District to a capacity of 222,000 acre-feet which it is estimated by the district will furnish a supply of two hundred million gallons daily. The Jackson Creek Spillway, located and designed to discharge surplus waters of the Mokelumne River into the Dry Creek watershed, also is constructed.

The drainage areas on the Mokelumne River watershed, above the Pardee Dam are segregated by zones of elevation as follows:

Area above elevation 5000 feet	317 square miles
Area between elevations 2500 and 5000 feet	194 square miles
Area below elevation 2500 feet	64 square miles
Total area above Pardee Dam	575 square miles

A contour map of the reservoir site, scale one inch equals 2000 feet, was prepared by Stephen E. Kieffer from surveys made in 1925. The East Bay Municipal Utility District prepared a contour map of the dam site, scale one inch equals 50 feet, in 1926. Table 71 sets forth areas and capacities for various heights of dam. These data were obtained from the East Bay Municipal Utility District.

The reservoir when filled to its present constructed capacity at flow line elevation 567.5 feet will be capable of diverting water through the Jackson Creek spillway. A larger storage capacity at this site is unnecessary as all spill therefrom probably can be conserved more economically in the Ione Reservoir.

The area included in the reservoir was undeveloped and without improvements. It consisted mostly of characteristic mountain land, steep, rocky and, in its natural state, partially covered with brush and small timber. All land below the flow line has been cleared. A full reservoir submerges an area of 2134 acres. The location of the existing dam and reservoir is shown on the location map on Plate XXX.

TABLE 71

AREAS AND CAPACITIES OF PARDEE RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
55	280	38	500
75	300	75	1,620
95	320	115	3,470
115	340	173	6,300
135	360	250	10,500
155	380	350	16,400
175	400	464	24,500
195	420	611	35,200
215	440	758	48,800
235	460	920	65,500
255	480	1,097	85,600
275	500	1,294	109,500
295	520	1,490	137,200
315	540	1,722	169,300
335	560	2,005	206,500
342.5	567.5	2,134	222,000

The dam is located in Section 26, Township 5 South, Range 10 East. It is of the arched gravity type, 343 feet in height from stream bed to crest and curved in plan to a radius of 1200 feet measured from the upstream or back line of the dam. The crest length is 1337 feet and the maximum thickness at stream bed 241 feet. A spillway with a capacity of 100,000 cubic feet per second is provided in a natural gap about 1000 feet south of the dam and has a total length of overflow of 800 feet. It discharges upon a broad apron of reinforced concrete and is gradually contracted by training walls into a canyon which leads back into the Mokelumne River about 1000 feet below the dam. The sluiceways consist of two 42-inch and two 72-inch diameter cast iron pipes. At the downstream end of each a Larner-Johnson discharge regulator and a butterfly valve of the same size as the sluiceway pipe are installed. A two-mile tunnel leads from an outlet tower in the reservoir to the main East Bay Municipal Utility District pipe line.

A power plant with an installed capacity of 18,750 kilovolt amperes located at the downstream toe of the dam is included in the project. It has two generators with a normal output capacity of 7500 kilowatts each. The maximum head on the power plant is 327.5 feet. The annual output was estimated by the district at from 70,000,000 to 125,000,000 kilowatt hours. From July 1, 1931, to June 30, 1932, the output was 58,966,300 kilowatt hours. The penstocks consist of two cast-iron pipes, 72 inches in diameter. A 72-inch butterfly valve is provided between each penstock and the water wheels of the power plant.

The Jackson Creek spillway is located at the head of Jackson Creek in a topographic saddle on the divide between the Mokelumne River and Dry Creek watersheds. It is a concrete structure of 16,000 second-feet capacity, consisting of a battery of sixteen siphons, each having throat dimensions of four by twelve feet. The siphons are provided with gates which are sealed at present. The structure was built with the idea of discharging surplus waters into the proposed storage reservoir on Dry Creek and will not be permitted to function until such time as the Ione Reservoir is constructed.

The following summary of costs of the Pardee development has been furnished by the East Bay Municipal Utility District.

Construction item	*Contract cost*	*Non-contract cost*
Pardee Reservoir	$337 35	$1,005,860 33
Pardee Dam	5,850,724 86	147,884 95
Pardee Power House	568,100 90	83,970 50
South Spillway	545,939 77	22,994 40
Jackson Creek Spillway	235,496 20	6,779 82
Reservoir roads	50,703 57	6,090 00
Reservoir fencing	----------	14,364 20
Railroad right of ways	----------	5,230 01
Pardee Outlet Tower	192,412 49	7,297 44
Pardee Tunnel	878,953 94	23,228 40
Camp Pardee	74,994 85	51,295 24
Patrolmen's houses	----------	12,250 17
Other items	----------	47,500 79
Direct costs	$8,397,663 93	$1,434,746 25
Total direct cost		9,832,410 18
Overhead (engineering, administration, etc.)		785,987 61
Interest during construction		409,979 80
Operating charges		7,512 38
Total Pardee development		$11,035,889 97

Water Supply and Yield—The average seasonal ultimate net run-off above Pardee Dam for the 40-year period, 1889–1929, is estimated at 820,000 acre-feet per season. Details of ultimate net run-off have been presented in Chapter II. In the State Plan, the present constructed reservoir would be operated in conjunction with the proposed Valley Springs Reservoir on Calaveras River, the Ione Reservoir on Dry Creek and the importation of water from the American River to furnish a surface supply with a maximum deficiency of 35 per cent, in an exceptionally dry year, to the irrigable areas in hydrographic divisions 12 and 12A. The combined yields and deficiencies are set forth in Chapter VII. With such coordinate operation, the estimated average annual irrigation yield for the 11-year period 1918–1929 from Pardee Reservoir alone would have been 294,000 acre-feet in addition to furnishing the East Bay Municipal Utility District a full supply of 200,000,000 gallons per day and an average annual spill into Ione Reservoir of about 92,500 acre-feet. In making these yield studies it was estimated that the net depth of evaporation loss from the reservoir surface would be 3.5 feet per season.

Other Developments on Mokelumne River—Above the Pardee reservoir, the North Fork of the Mokelumne River has been developed for hydroelectric power by the Pacific Gas and Electric Company. The system includes six storage reservoirs, three forebay reservoirs, one afterbay, three canals and three power houses. The principal physical features of the larger reservoirs are as follows:

Reservoir	*Drainage area, in square miles*	*Water surface elevation, in feet*	*Height of dam above streambed, in feet*	*Capacity, in acre-feet*
Salt Springs	160.0	3,947	300	130,000
Twin Lakes	0.8	8,172	22	1,309
Upper Blue Lake	2.7	8,131	31	7,106
Lower Blue Lake	4.8	8,040	48	4,190
Meadow Lake	5.5	7,773	73	6,021
Bear River Reservoir	28.5	5,875	80	6,712
Tabeaud Forebay	2.0	1,960	120	1,200
Tiger Creek Afterbay	360.0	2,331	105	3,800
Total				160,338

The power plants have a total installed generating capacity of 91,000 kilovolt-amperes, segregated as follows:

Power plant	*Installation in kilovolt amperes*
Salt Springs	11,000
Tiger Creek	60,000
Electra	20,000
Total	91,000

PLATE XXXI

PARDEE DAM ON MOKELUMNE RIVER

Further storage development is projected on Bear River and additional power installations are contemplated at Salt Springs, Electra and West Point. These developments would result in additional installed capacities of 30,000 kilovolt amperes at Salt Springs, 15,000 kilovolt amperes at West Point and 40,000 kilovolt amperes at Electra.

Small diversions are made through power company ditches for domestic use in the town of Jackson. Many diversions have been made through ditches on the headwaters of the stream for mining use. Records as to amounts diverted are not available. Most of these ditches have been abandoned and the amounts taken by those still operating are believed to be relatively small.

Diversion from the Mokelumne River below the Pardee Dam is made by the Woodbridge Irrigation District, containing a gross area of 13,851 acres, of which 6184 acres were irrigated in 1929. Approximately 4000 acres of riparian lands are irrigated by pumping plants located along the river between Pardee Dam and the mouth of Dry Creek.

Valley Springs Reservoir on Calaveras River.

The dam site for the Valley Springs Reservoir is located in a narrow canyon just below the confluence of Bear Creek and the main river in the southwest quarter of Section 31, Township 4 North, Range 11 East, M.D.B. and M., about three miles southerly from the town of Valley Springs, in Calaveras County. Immediately above the dam site the canyon widens out into a broad basin. The reservoir site extends to the forks of the Calaveras River about two miles west of San Andreas.

The Hogan Dam recently has been completed by the City of Stockton at the Valley Springs dam site for the purpose of controlling floods on the Calaveras River to afford flood protection to Stockton and adjacent areas. The completed structure is a concrete variable radius arch dam with concrete gravity type abutments. The spillway, with an overall length of 616.25 feet, extends for the entire length of the arch. The spillway crest is at two elevations, the central portion, 375 feet long, having its crest at elevation 637.5 and adjoining portions on either side having a crest elevation of 649 feet. The maximum height of the arch dam in the center of the spillway is 107.5 feet above stream-bed. The capacity of the reservoir at elevation 637.5 feet is 76,000 acre-feet. The crests of the gravity abutments are at elevation 655.5 feet. An earth embankment 227 feet in length is constructed at the extreme end of the right abutment. Nine flood control outlets, 5½ feet in diameter, are provided through the dam. Four of these outlets are at elevation 557 feet, three at elevation 584 feet and one each at elevation 600 feet and 614 feet. These flood openings have no gate controls. The discharge capacity of these flood openings, with a reservoir level at elevation 655.5, is approximately 12,800 second-feet. The capacity of the spillway with this same reservoir level is approximately 96,000 second-feet, making the combined capacity of the spillway and flood outlets approximately 108,800 second-feet. The cost of the structure is reported as $1,189,157. Tentative plans are proposed for raising the dam sometime in the future to increase the reservoir capacity to 165,000 acre-feet for the purpose of obtaining a greater degree of flood protection than that afforded by the present structure.

Preliminary investigations were made of several other sites. The principal ones are the North Branch site on the main river, the Kentucky House site on the South Fork and the McCarthy site on the North Fork. These investigations showed the Valley Springs site to be the most suitable for the purpose desired.

The drainage areas on the Calaveras River watershed, above the Valley Springs dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	3 square miles
Area between elevations 2500 and 5000 feet	90 square miles
Area below elevation 2500 feet	270 square miles
Total area above Valley Springs dam site	363 square miles

Present Developments on Calaveras River—There are no important diversions above the Valley Springs dam site. Below the site, from Jenny Lind to Stockton, a number of pumping plants divert water from the river for agricultural purposes. No information is at hand to indicate the extent and amount of these diversions. The recently organized Linden Irrigation District of 13,700 acres proposes to secure water from the Calaveras River. About 6000 acres in this district were irrigated from wells in 1929.

Water Supply—The water supply which would be regulated in the Valley Springs reservoir is the ultimate net run-off of the Calaveras River, averaging 189,000 acre-feet per season for the 40-year period 1889–1929.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 500 feet, was prepared by Galloway and Markwart from a survey made in 1910. The city of Stockton prepared a contour map of the dam site, scale one inch equals 50 feet, in 1925. Table 72 sets forth areas and capacities for various heights of dam based on those surveys.

TABLE 72

AREAS AND CAPACITIES OF VALLEY SPRINGS RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
15	540	23	100
35	560	184	1,900
55	580	482	8,500
75	600	872	22,000
95	620	1,354	44,200
115	640	1,837	76,200
135	660	2,342	117,900
155	680	2,904	170,300
175	700	3,489	234,200
195	720	4,167	310,600
200	725	4,300	325,000
205	730	4,545	354,100

The capacity of the reservoir proposed for ultimate development is 325,000 acre-feet. It would have a flow line elevation of 725 feet. Water would be backed up to the junction of the North and South forks, a distance of about eight miles, submerging an area of 4300 acres. A reservoir capacity of 160,000 acre-feet is required, in addition to the projected capacity of 165,000 acre-feet for flood control, for the purpose of equalizing the flow to meet irrigation demands. This additional capacity would have regulated the entire available stream flow of the Calaveras River for the 11-year period, 1918–1929. This would have been accomplished without infringing on the flood regulation capacity of 165,000 acre-feet desired and partially developed by the city of Stockton to control flood flows to a maximum of 25,000 second-feet which would be exceeded once in 100 years on the average. This amount of flood control capacity was added to give the total selected reservoir capacity. The Calaveras Reservoir would be operated coordinately with the Pardee and Ione reservoirs and imported water supplies from the American River to provide the water requirements in hydrographic divisions 12 and 12A. With such coordinate operation, the capacity proposed for irrigation alone would have furnished an average seasonal yield for the 11-year period 1918–1929 of 98,000 acre-feet. In making the yield studies at this site, it was estimated that the net seasonal evaporation loss would be 3.5 feet in depth on the reservoir surface. Details of reservoir yield and utilization are given in Chapter VII.

There is some agricultural land within the proposed reservoir, but most of the area to be flooded, above the present city of Stockton reservoir, is grazing land. There are few county roads traversing the reservoir site which are not flooded by the existing development. The flow line of the proposed reservoir may come sufficiently close to the roadbed and bridge floors of the Lodi-San Andreas highway to necessitate construction of new bridges over the North Fork and North Branch Creek, and relocation of about one and one-quarter miles of highway. The flow line also may be sufficiently high on the grade of the Southern Pacific-Calaveras Cement Company Railway to require relocation of about three miles of that line, together with the construction of a bridge over the North Fork. For this reason both the highway and railroad relocations have been included in the reservoir cost estimate.

Dam Site—Previous to the construction of the present dam by the city of Stockton, the site was tested by diamond drill borings, and much additional information was secured during construction as to the adequacy of the foundations and probable depth of stripping required for the proposed structure. Sound rock is found at shallow depths at and near the stream bed, at depths ranging from 15 to 50 feet on the right abutment and from 10 to 40 feet on the left. The character of the bedrock is entirely satisfactory for supporting the proposed structure.

Dam and Appurtenances—Topography of the dam site and general layout of the proposed dam and appurtenances required to effect the desired irrigation storage and flood control are shown on Plate

PLATE XXXII

HOGAN DAM ON CALAVERAS RIVER

XXXIII, "Valley Springs Reservoir on Calaveras River." The dam is a concrete gravity type structure, having a maximum height of 200 feet above streambed, and slightly curved in plan to follow a ridge on either side of the canyon. The overflow spillway, located at the left abutment of the dam and controlled by nine steel drum gates 20 feet high by 50 feet long, would discharge into a natural draw that joins the river about a quarter of a mile below the dam site. The spillway capacity with 5 feet of freeboard on the dam is estimated at 140,000 second-feet or about two and one-half times the once-in-25-year flood.

The reserve space of 165,000 acre-feet proposed for flood control, would require a maximum drawdown of 48 feet. Regulation would be obtained by ten 9-foot by 9-foot openings through the dam with a center line elevation of 652 feet, controlled by sluice gates of the caterpillar type. Floods could be controlled to a maximum value of 25,000 second-feet, exceeded once in one hundred years on the average. Irrigation water would be released through two 42-inch diameter pipes having a combined discharging capacity of 800 second-feet, under a minimum head of 50 feet. The elevation of outlets is 540 feet. The releases would be controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

Cost of Valley Springs Reservoir—The capital and annual costs of Valley Springs Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 73. Since the proposed dam would provide equivalent flood protection to that proposed by the city of Stockton, the cost estimate does not include any amount for the value of the present dam.

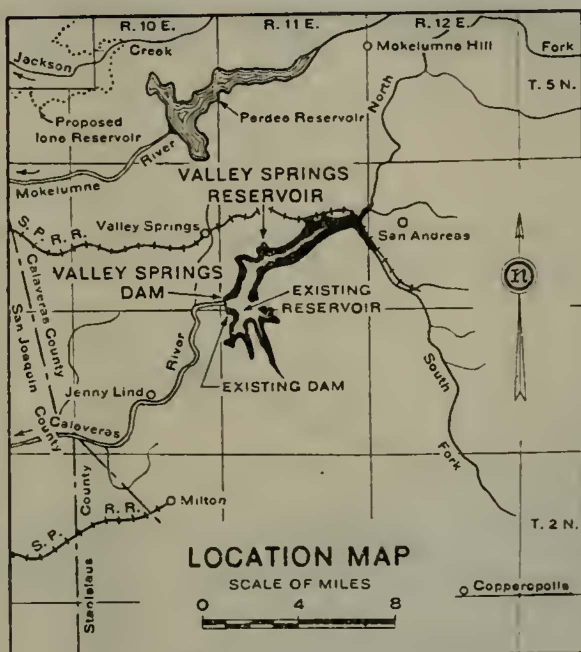
TABLE 73

COST OF VALLEY SPRINGS RESERVOIR

Height of dam, 200 feet. Capacity of reservoir, 325,000 acre-feet.
Capacity of spillway, 140,000 second-feet.
Capacity of irrigation outlets, 800 second-feet.
Capacity of flood control outlets, 25,000 second-feet.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		830,000
Excavation for dam, 339,000 cubic yards at $1.00 to $5.00	$860,000	
Mass concrete, 490,000 cubic yards at $6.30	3,087,000	
Reinforced concrete, 5,700 cubic yards at $18 to $30	120,000	
Spillway gates	270,000	
Spillway channel	220,000	
Irrigation outlets and sluiceways	50,000	
Flood control outlets	76,000	
Drilling, grouting, drains and contraction seals	100,000	
		4,783,000
Miscellaneous		41,000
Subtotal		$5,684,000
Administration and engineering at 10 per cent		568,000
Contingencies at 15 per cent		853,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		495,000
Total capital cost of dam and reservoir		$7,600,000
Total annual cost of dam and reservoir		$452,000

In calculating the annual cost, it was assumed that the city of Stockton would pay the cost of the bonded indebtedness on the present development since it would receive at least equivalent service under the State Plan. Therefore, the figure for annual cost does not include any amount for the annual cost of the present dam and reservoir but does



VALLEY SPRINGS RESERVOIR

ON

CALAVERAS RIVER

XXXIII, "Valley Springs Reservoir on Calaveras River." The dam is a concrete gravity type structure, having a maximum height of 200 feet above streambed, and slightly curved in plan to follow a ridge on either side of the canyon. The overflow spillway, located at the left abutment of the dam and controlled by nine steel drum gates 20 feet high by 50 feet long, would discharge into a natural draw that joins the river about a quarter of a mile below the dam site. The spillway capacity with 5 feet of freeboard on the dam is estimated at 140,000 second-feet or about two and one-half times the once-in-25-year flood.

The reserve space of 165,000 acre-feet proposed for flood control, would require a maximum drawdown of 48 feet. Regulation would be obtained by ten 9-foot by 9-foot openings through the dam with a center line elevation of 652 feet, controlled by sluice gates of the caterpillar type. Floods could be controlled to a maximum value of 25,000 second-feet, exceeded once in one hundred years on the average. Irrigation water would be released through two 42-inch diameter pipes having a combined discharging capacity of 800 second-feet, under a minimum head of 50 feet. The elevation of outlets is 540 feet. The releases would be controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

Cost of Valley Springs Reservoir—The capital and annual costs of Valley Springs Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 73. Since the proposed dam would provide equivalent flood protection to that proposed by the city of Stockton, the cost estimate does not include any amount for the value of the present dam.

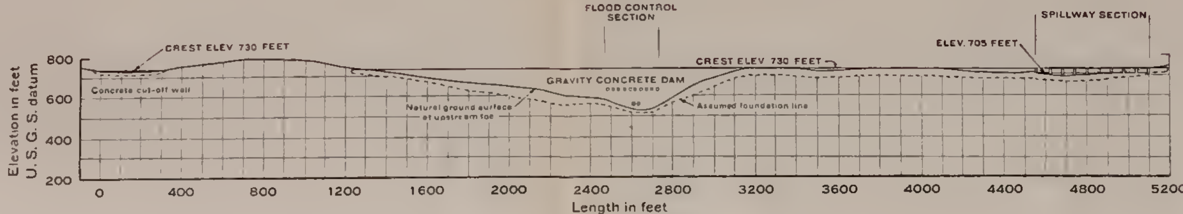
TABLE 73

COST OF VALLEY SPRINGS RESERVOIR

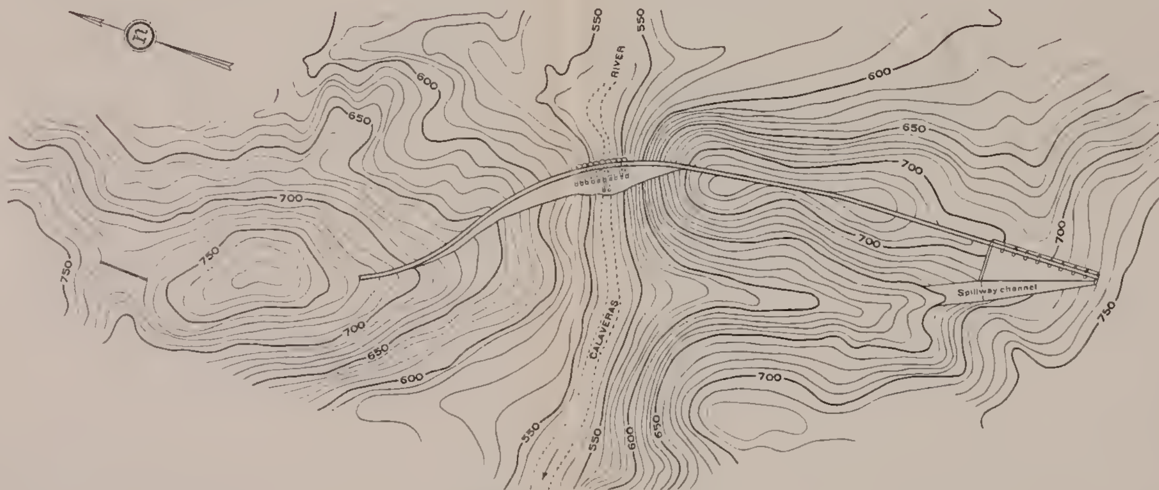
Height of dam, 200 feet. Capacity of reservoir, 325,000 acre-feet.
Capacity of spillway, 140,000 second-feet.
Capacity of irrigation outlets, 800 second-feet.
Capacity of flood control outlets, 25,000 second-feet.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		830,000
Excavation for dam, 339,000 cubic yards at $1.00 to $5.00	$860,000	
Mass concrete, 490,000 cubic yards at $6.30	3,087,000	
Reinforced concrete, 5,700 cubic yards at $18 to $30	120,000	
Spillway gates	270,000	
Spillway channel	220,000	
Irrigation outlets and sluiceways	50,000	
Flood control outlets	76,000	
Drilling, grouting, drains and contraction seals	100,000	
		4,783,000
Miscellaneous		41,000
Subtotal		$5,684,000
Administration and engineering at 10 per cent		568,000
Contingencies at 15 per cent		853,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		495,000
Total capital cost of dam and reservoir		$7,600,000
Total annual cost of dam and reservoir		$452,000

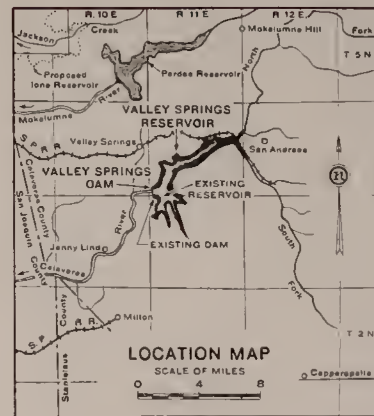
In calculating the annual cost, it was assumed that the city of Stockton would pay the cost of the bonded indebtedness on the present development since it would receive at least equivalent service under the State Plan. Therefore, the figure for annual cost does not include any amount for the annual cost of the present dam and reservoir but does



PROFILE OF DAM
LOOKING UPSTREAM



GENERAL PLAN OF DAM
FEET
0 400 800



LOCATION MAP
SCALE OF MILES
0 4 8

VALLEY SPRINGS RESERVOIR
ON
CALAVERAS RIVER

include the cost of furnishing the service now rendered by the present development by means of the proposed works.

Melones Reservoir on Stanislaus River.

The dam site for the Melones reservoir on the Stanislaus River is located about 1000 feet upstream from the existing Melones Power Plant and about 3600 feet downstream from the constructed Melones dam of the South San Joaquin and Oakdale irrigation districts. It is situated in what is known locally as Iron Canyon in the southeast quarter of Section 10 and the southwest quarter of Section 11, Township 1 North, Range 13 East, M.D.B. and M., about six miles westerly from the town of Jamestown, in Calaveras and Tuolumne counties.

Two other reservoir sites, one with a dam at the Black Creek dam site about eight miles below the Melones site and the other with a dam at the Robinson's Ferry dam site about 11.5 miles above the Melones site, were investigated, but it was found that their potential capacities were inadequate to give the desired regulation of the run-off of the Stanislaus River. The Melones site is the only one capable of being developed to the required capacity.

The drainage areas on the Stanislaus River watershed, above the Melones dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	555 square miles
Area between elevations 2500 and 5000 feet	205 square miles
Area below elevation 2500 feet	140 square miles
Total area above Melones dam site	900 square miles

Present Developments on Stanislaus River—Above the Melones site, the conduit of the Utica Mining Company, with a capacity of 88 second-feet, diverts water from the North Fork about seven miles above its junction with Middle Fork. The water is carried a distance of 23 miles to the vicinity of Murphy where it is dropped 527 feet to a power plant on Angels Creek. Part of the water is then used for irrigation, mining and domestic purposes near the towns of Murphy, Vallecito and Angels. A total of 1400 acres is irrigated by the system. About three miles below the power plant, water is rediverted from Angels Creek to the forebay of Angels Power Plant. Here it is dropped 450 feet and, after passing through the plant, flows down the creek to the Stanislaus River above the Melones site. The electrical installation at Murphy is 1500 kilovolt amperes and at Angels 650 kilovolt amperes. The Pacific Gas and Electric Company has an extensive power development on the Middle and South Forks. The Spring Gap Plant, with an installed capacity of 7500 kilovolt amperes, and the Stanislaus Power Plant, with an installed capacity of 34,000 kilovolt amperes, are located on the Middle Fork. Water also is diverted from the South Fork to the latter plant. The Phoenix Plant, with an installed capacity of 1875 kilovolt amperes, is located on Sullivan Creek in the Tuolumne River watershed, but receives its water through the old Main Tuolumne Ditch which heads at an altitude of 4000 feet at Lyons Dam Reservoir on the South Fork of Stanislaus River. The Melones Mining Company Power Plant (now owned by the South San Joaquin and Oakdale irrigation districts and leased to the Pacific Gas and Electric Company), with an installed capacity of 1000 kilovolt amperes, is located about seven miles upstream from the existing Melones Dam and diverts water from the main Stanislaus River.

In connection with the foregoing power developments, many reservoirs have been constructed. The larger of these have a combined storage capacity of 55,900 acre-feet, distributed as follows:

Relief Reservoir on Relief Creek	15,100 acre-feet
Utica Reservoir on North Fork	2,400 acre-feet
Union Reservoir on North Fork	2,000 acre-feet
Silver Valley Reservoir on North Fork	4,600 acre-feet
Upper Strawberry Reservoir on South Fork	1,200 acre-feet
Lower Strawberry Reservoir on South Fork	17,900 acre-feet
Lyons Dam Reservoir on South Fork	5,500 acre-feet
Spicer Meadows Reservoir on Highland Creek	7,200 acre-feet

The South San Joaquin and Oakdale irrigation districts jointly have constructed a reservoir at the Melones site, with a storage capacity of 112,500 acre-feet. The dam is located about 3600 feet upstream from the dam site proposed for ultimate development. It is arched in plan, has a height of 183 feet above stream bed and a crest length of 590 feet. The center section, 450 feet in length, has a constant radius of 238 feet on the upstream face. The wings are of the gravity type, with a combined length of 140 feet. The spillway extends across the top of the dam, and is divided by piers into nine sections, each containing a steel drum gate. An outlet tunnel equipped with large needle valves enters the reservoir beneath the south abutment. This tunnel extends downstream below the irrigation outlet valves to supply a power plant of the Pacific Gas and Electric Company having an installed capacity of 27,000 kilovolt amperes.

The project was constructed under an agreement, dated January 2, 1925, between the two districts and the Pacific Gas and Electric Company. Under the terms of this agreement, the maximum capacity of Melones Reservoir is fixed at 112,500 acre-feet, with 103,500 acre-feet available for withdrawal each year, to be shared equally between the two districts. The cost of Melones Dam and Reservoir, amounting to $2,351,000, is divided equally between the two districts. The power company constructed and bore the cost of the power plant below the dam. From March 1 to October 31 of each year the control of the stored water is in the hands of the districts, with the maximum withdrawal from stored water to be at the rate of 1500 second-feet. All inflows less than 1000 second-feet must be released through the power plant. The releases for irrigation pass through the power plant when needed. From November 1 to March 1 operation of the reservoir is placed under the direction of the power company, which must release sufficient water to fill a lower reservoir as well as any additional water needed by the districts for irrigation or domestic use. For the use of water passing through Melones Reservoir, the power company pays to the two districts, jointly, the sum of $5,175,000 in semiannual installments of $64,687.50, these payments to be used by the districts to cover interest and principal of the bonds issued for the construction of Melones Dam. When the bonds have been fully paid, this income is to be available to the districts for other purposes. Other provisions of the contract cover storage rights of the power company above Melones Reservoir, release of the water so stored to the districts, maintenance and upkeep of the reservoir and other related matters.

The Oakdale Irrigation District has a gross area of 74,240 acres of which 23,321 acres were irrigated in 1929, and the South San Joaquin Irrigation District a gross area of 71,112 acres of which 54,340 acres were irrigated in the same year.

Water Supply—The water supply available for regulation at the Melones site would be the ultimate net run-off of the Stanislaus River for which the mean seasonal value for the 40-year period, 1889–1929, is estimated at 1,239,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the proposed dam site, scale one inch equals 100 feet, was made by the State in 1930. The areas and capacities of reservoirs for various heights of dam, as set forth in Table 74, have been obtained up to elevation 740 feet from the contour map for the existing reservoir, scale one inch equals 200 feet, prepared by the South San Joaquin and Oakdale irrigation districts in 1921. For areas and capacities above that elevation, the U. S. G. S. topographic maps were used.

TABLE 74

AREAS AND CAPACITIES OF MELONES RESERVOIR

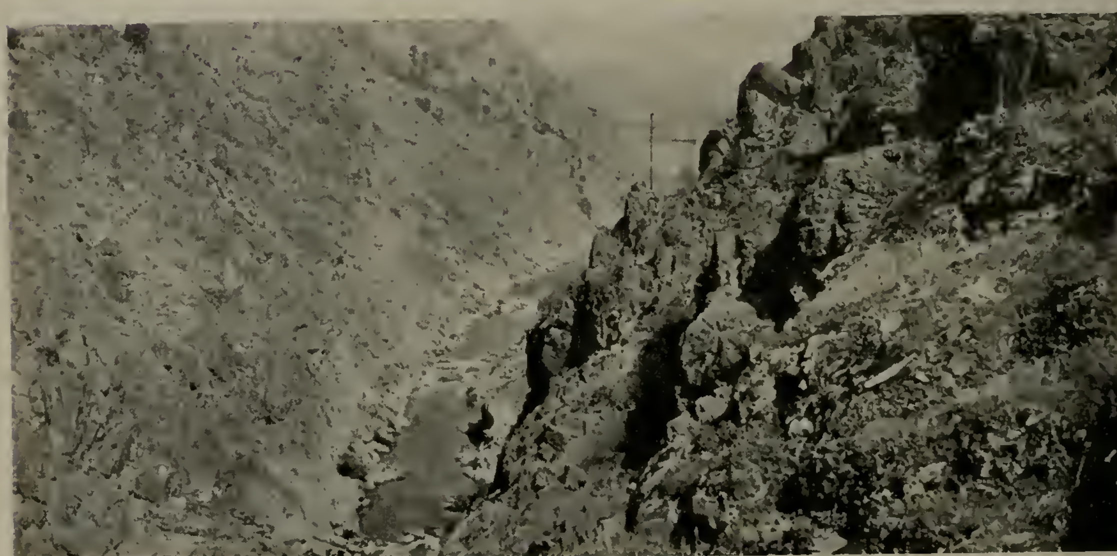
Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
115	620	220	4,500
135	640	420	10,700
155	660	680	21,500
175	680	930	37,600
195	700	1,220	59,000
215	720	1,560	87,000
235	740	1,940	122,000
255	760	2,300	165,000
275	780	2,650	215,000
295	800	3,070	272,000
315	820	3,550	336,000
335	840	4,050	409,000
355	860	4,550	492,000
375	880	5,000	590,000
395	900	5,540	702,000
415	920	6,200	808,000
435	940	6,850	927,000
455	960	7,500	1,059,000
460	965	7,700	1,090,000
475	980	8,150	1,203,000
495	1,000	8,770	1,368,000

The capacity selected for the proposed Melones Reservoir is 1,090,000 acre-feet. This size of reservoir is required to furnish a dependable surface irrigation supply to the lands which are and would be dependent naturally on the Stanislaus River for such supply. This supply could have been made available by this reservoir during the 40-year period, 1889–1929, without resort to ground water storage with an average deficiency of less than two per cent per year. It would have a flow line elevation of 965 feet. At this elevation the reservoir basin would have a length of ten miles and a maximum width of one and one-quarter miles. The area flooded would be 7700 acres.

The flooded area, exclusive of that now included in the present Melones Reservoir, consists of 5880 acres of rough mountainous land.

PLATE XXXIV

Present Melones Dam Completed in 1926



Site of Proposed Dam Below Existing Structure

Present Melones Powerhouse Below Site of Proposed Dam

MELONES DAM SITE ON STANISLAUS RIVER

The Mother Lode, embracing valuable mines and mining claims, crosses the site. The most important of these mines is Carson Hill Mine of Carson Hill group. The workings, mill, cyanide plant and other structures of the mine would be flooded. The small power plant of 1000 kilovolt amperes installation, owned by the South San Joaquin and Oakdale irrigation districts and leased to the Pacific Gas and Electric Company, also is below the proposed flow line. The Mother Lode Highway, between Sonora and Angels, the Robinson's Ferry County Road and the Angels branch of the Sierra Railway also would be flooded and would require relocation.

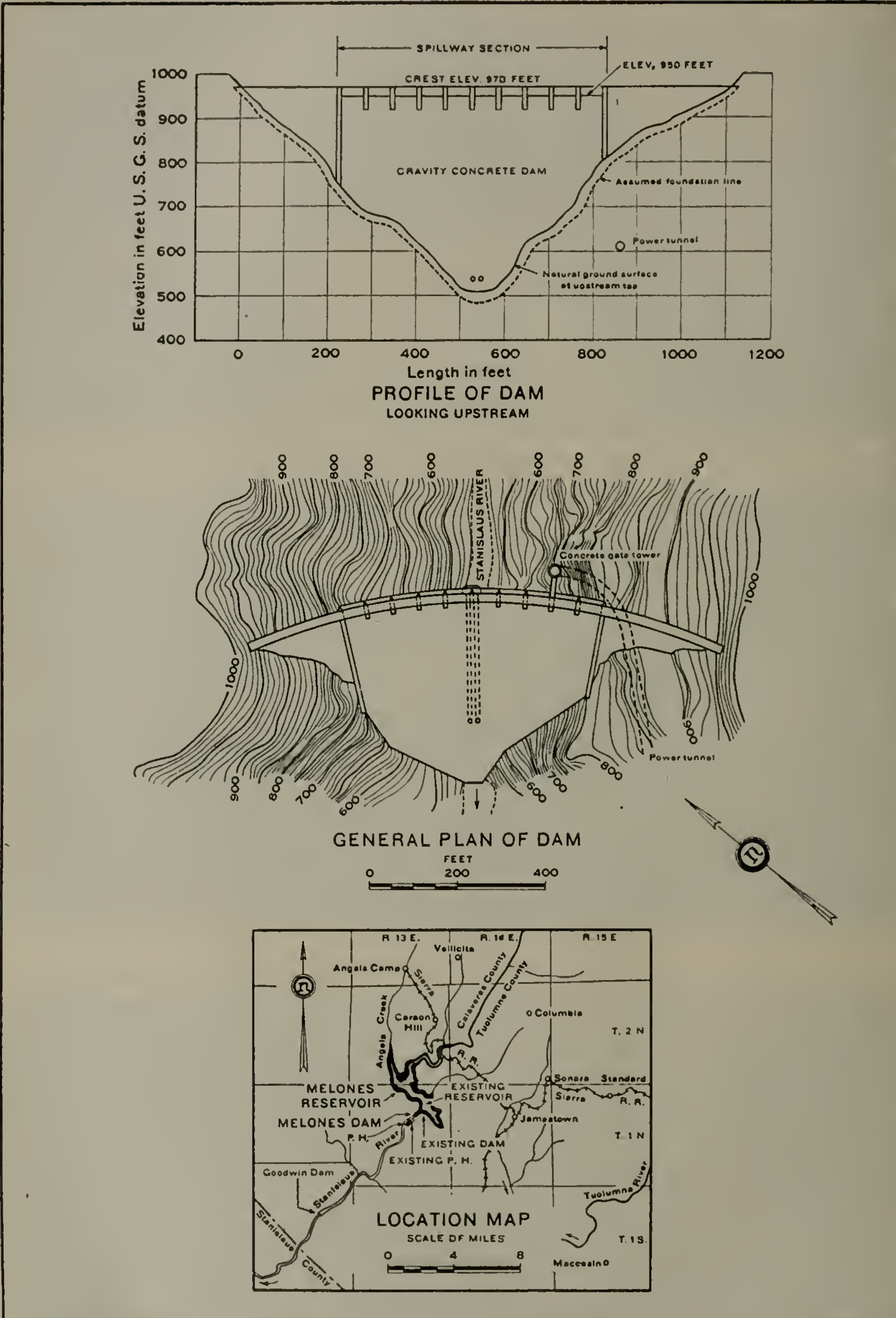
The safe surface irrigation yield of the proposed reservoir for the 40-year period, 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per season on the average and 35 per cent as a possible maximum in an exceptionally dry year, would have been 905,000 acre-feet. The mean seasonal irrigation yield for the 40-year period would have been 887,000 acre-feet. A net seasonal evaporation loss of 3.5 feet depth on the reservoir surface was used in making yield studies at this site. Details of reservoir yields and utilization are given in Chapter VII.

Dam Site—A geological examination shows the site to be suitable for a high concrete structure. The topographic and geologic features of this site are similar to those of the Nashville site on the Cosumnes River. The stream has developed a deep "V" shaped gorge with cliff profile at the dam site through a dike-like rock mass, consisting of a fine grained dark green diabase. No exploration has been made at this site, but from field examination it is estimated that stripping to average depths of fifteen feet normal to the slope on the right abutment and 20 feet normal to the slope on the left abutment will remove all loose material and reveal rock which, although jointed, could be rendered sound by pressure grouting. The width of the stream bed varies from 30 to 50 feet and it is believed that a good foundation can be secured therein by excavating to depths of from 15 to 20 feet.

Dam and Appurtenances—Topography of the dam site and general layout of the proposed dam and appurtenances are shown on Plate XXXV, "Melones Reservoir on Stanislaus River." The height of dam above stream bed is 460 feet, including five feet of freeboard. It is a concrete gravity type dam with a centrally located overflow spillway section controlled by ten steel drum gates 15 feet high by 50 feet long. The estimated discharging capacity of the spillway is 120,000 second-feet or two and four-tenths times the estimated once-in-25-year-flood.

Reserve storage space of 204,000 acre-feet, with a maximum draw-down of 34 feet, is proposed for flood control. The utilization of this space would result in a controlled flow of 15,000 second-feet, exceeded once in one hundred years on the average. The required outlet capacity for flood regulation is provided by the irrigation and power plant outlets, with reservoir surface at elevation 930 feet, assuming that turbine by-passes are provided in the power plant. Irrigation outlets are provided for a discharging capacity of 2700 second-feet by means of two 78-inch diameter pipes through the dam, controlled by needle valves and also emergency slide gates.

PLATE XXXV



MELONES RESERVOIR

ON

STANISLAUS RIVER

Power Plant—The economic power plant installation has been determined as 68,000 kilovolt amperes, based on a value of power of $0.003 per kilowatt hour. The power plant is located about one-quarter mile downstream from the dam on the left bank of the stream. It would be supplied through an outlet pressure tunnel, located under the dam on the left bank. The intake of the tunnel consists of a cylindrical reinforced concrete tower having a balanced cylinder valve to be used for unwatering the tunnel and for emergency closures. Adits lead from the main tunnel to the face of the hill where they would discharge into steel pipes leading to each turbine. These pipes are equipped with needle valves at each turbine inlet. A surge tank and shaft carried to a point slightly above the flow line elevation of the reservoir is located at the downstream end of the main tunnel. The power plant consists of four 17,000 kilovolt ampere units, equipped with turbine by-passes. It would replace the present Melones Power Plant which has an installed capacity of 27,000 kilovolt amperes. The cost of the power development is estimated at approximately $60 per kilovolt ampere.

Cost of Melones Reservoir—The capital and annual costs of Melones reservoir and power plant, estimated in accord with bases previously presented in this chapter, are shown in Table 75. Estimates also are shown of revenue from sale of electric energy and the net annual cost after deducting power revenue. The tabulated costs do not include any amounts for the destruction of the present Melones Dam of the South San Joaquin and Oakdale irrigation districts or for any possible interference with the existing power development in connection therewith. It is contemplated that interests and lands now receiving service, both irrigation and power, from the present development would continue to receive the same service with no additional cost under the larger development as proposed herein for the State Water Plan. Therefore, in accord with such assumption, the commitments and obligations of the parties now interested in the present development would be maintained without modification. The figure for annual cost includes no amount for present development, but does include amounts for equivalent service which would be rendered with the larger State proposal. It is not possible to foretell the conditions under which, or when or by whom, the proposed development would be constructed. Neither is it possible to state whether or not the present development would be entirely amortized and depreciated at the time the proposed development is undertaken. Therefore, the entire anticipated power revenue has been credited to the proposed unit and deducted from the gross annual cost to obtain the net annual cost.

TABLE 75

COST OF MELONES RESERVOIR

Height of dam, 460 feet. Capacity of reservoir, 1,090,000 acre-feet.
Capacity of spillway, 120,000 second-feet.
Capacity of irrigation outlets, 2,700 second-feet.
Flood control outlet capacity of 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		4,660,000
Excavation for dam, 185,000 cubic yards at $3.00 to $5.00	$761,000	
Mass concrete, 1,318,000 cubic yards at $7.90	10,412,000	
Reinforced concrete, 3,500 cubic yards at $18.00 to $30.00	72,000	
Spillway gates	200,000	
Irrigation outlets and sluiceways	185,000	
(Power plant outlets and tunnels included in cost of power plant).		
Drilling, grouting, drains and contraction seals	88,000	
		11,718,000
Miscellaneous		196,000
Subtotal		$16,604,000
Administration and engineering at 10 per cent		1,660,000
Contingencies at 15 per cent		2,491,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,445,000
Total capital cost of dam and reservoir		$22,200,000

Cost of Power Plant for Melones Reservoir

Installed capacity, 68,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total cost of power plant, including all appurtenances	$4,000,000

Annual Cost of Melones Reservoir and Power Plant

Gross annual cost of dam and reservoir	$1,334,000
Gross annual cost of power plant	323,000
Total gross annual cost	1,657,000
Average annual revenue from sale of electric energy, 240,000,000 kilowatt hours at $0.003	720,000
Average net annual cost, not covered by revenue from sale of electric energy	937,000

Don Pedro Reservoir on Tuolumne River.

Two reservoir sites on the lower reaches of the Tuolumne River were investigated as possibilities for units in the State Water Plan, namely: Don Pedro and Jacksonville sites. The dam site for the Don Pedro Reservoir is on the main river about one-half mile downstream from the existing dam of the Modesto and Turlock irrigation districts in the southeast quarter of Section 34, Township 2 South, Range 14 East, M.D.B. and M., and about four miles northeasterly from the town of La Grange. Upstream from the Don Pedro site is the Jacksonville dam site in Section 24, Township 1 South, Range 14 East, M.D.B. and M. It is on the main river below the mouth of Woods Creek at a stream bed elevation of about 536 feet. These two sites are the only ones located on the lower reaches of Tuolumne River capable of adequately regulating the run-off of the stream. The drainage area above the Don Pedro site is 1536 square miles and above the Jacksonville site, 1451 square miles. The Don Pedro site is capable of being developed to larger capacity than the Jacksonville site. Both reservoirs are limited, in the practicable height to which a dam can be constructed, by the Moccasin Creek Power Plant, the tail race of which is 920 feet. The capacity of the Don Pedro Reservoir constructed to that elevation would be 2,580,000 acre-feet and for the Jacksonville Reservoir 493,000 acre-feet. The height of dams would be 604 feet and 394 feet respectively. From geological examinations it has been determined that the Don Pedro site is satisfactory for a masonry dam or any other type of dam. The Jacksonville site is uncertain, even for a rockfill dam, because of unsuitable foundation conditions. A fault passes through this latter site. Cost estimates reveal that the cost per acre-foot of storage at the Jacksonville site would be several times that at the Don Pedro site. Because of its greater available potential storage capacity, more favorable dam foundation, greater tributary drainage and lower unit cost of storage, the Don Pedro site was chosen over the Jacksonville site.

The drainage areas on the Tuolumne River watershed, above the Don Pedro dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	920 square miles
Area between elevations 2500 and 5000 feet	375 square miles
Area below elevation 2500 feet	241 square miles
Total area above Don Pedro dam site	1536 square miles

Present Developments on Tuolumne River—The water developments above the Don Pedro dam site of the State Water Plan comprise those for the municipal water supply of the city of San Francisco and the irrigation supply of the Turlock and Modesto irrigation districts. The Hetch Hetchy and Lake Eleanor reservoirs of the city of San Francisco are in the upper part of the watershed. The O'Shaughnessy Dam of the Hetch Hetchy Reservoir is located in Section 16, Township 1 North, Range 20 East, M.D.B. and M., on the main stream at stream bed elevation 3500 feet. The initial reservoir impounds 206,000 acre-feet. With the dam raised 85 feet to its proposed ultimate height, the capacity would be 348,500 acre-feet. The drainage area above the dam is 459 square miles. The dam of Lake Eleanor Reservoir is located in Section 3, Township 1 North, Range 19 East, M.D.B. and M., on Eleanor Creek at stream bed elevation of 4600 feet. It has been constructed to a capacity of 27,800 acre-feet and the plans of the city of San Francisco call for the construction of a dam at this site to an ultimate height of 225 feet, which would impound 218,000 acre-feet. The drainage area above the dam is 79 square miles, which would be increased to 193 square miles if the drainage area above a proposed diversion from the Cherry Creek watershed be included. The ultimate plans of the city of San Francisco include storage development at five other reservoir sites, namely: Poopenant Valley, Cherry Valley, Lake Vernon, Huckleberry Lake and Emigrant Lake with a total storage capacity of about 205,000 acre-feet. If these plans are fully executed a total storage capacity of about 770,000 acre-feet, including Hetch Hetchy and Lake Eleanor reservoirs, will be developed for the regulation of the run-off from a total tributary drainage area of 666 square miles on the upper Tuolumne River watershed. In addition to the run-off from that area there would still remain the run-off from 877 square miles of watershed above the valley floor to be regulated. The total drainage area above the valley floor is 1543 square miles. In connection with the foregoing development the city of San Francisco has constructed the Moccasin Creek and Cherry Creek power plants with capacities of 80,000 and 3000 kilovolt amperes, respectively. Plans for ultimate municipal water supply development include extensive additional power installations.

The present Don Pedro Reservoir and Power Plant, constructed jointly by the Modesto and Turlock irrigation districts at a cost of more than $5,000,000, has a storage capacity of 290,000 acre-feet. The dam has a height of 270 feet, a crest length of 1020 feet and a maximum base thickness of 177 feet. It is a concrete gravity-type dam, curved in plan with a constant radius. An overflow wing-type spillway and spillway channel located on the right abutment of the dam was designed for an estimated discharging capacity of 125,000 second-feet. The discharge is controlled by ten steel drum-type gates, nine feet high by 57 feet long, installed on the spillway crest. Three 60-inch sluiceways extend through the dam, 254 feet below its crest, controlled by slide gates at the upstream face of the dam. Two batteries of irrigation outlets are placed 98 and 188 feet, respectively, below the crest of the dam. Each battery consists of six 52-inch diameter outlets. The power plant is located at the downstream toe of the dam on the left bank of the stream. It is equipped with five turbine and generator units having an aggregate installed capacity of 33,740 kilovolt amperes. Water is supplied to the turbines through 72-inch penstocks. Each penstock is located in the base of the dam for part of its length, but the downstream portions are excavated in solid rock. Slide gates are installed near the upstream end of each penstock for emergency control. The turbines discharge vertically downward into a tunnel outlet. The diversion of the irrigation supply from the river is accomplished at the La Grange Dam, four miles below Don Pedro Dam. The La Grange Dam, at the time of its construction in 1893, was one of the highest overpour structures in existence. It is built of masonry, has a height of 131 feet above stream bed and cost a little more than $500,000. Below the La Grange Dam, the Turlock Irrigation District has constructed the La Grange Power Plant, with an installed capacity of 4750 kilovolt amperes, which is used chiefly for stand-by purposes.

The Modesto Irrigation District paid 31.54 per cent and the Turlock Irrigation District 68.46 per cent of the cost of the Don Pedro Project. The storage and power releases are owned in the same proportion. The Modesto District owns and operates its own power distribution system and retails all of its power for agricultural, domestic and industrial uses.

The Turlock District, on June 21, 1922, voted to distribute its share of the Don Pedro power output and, on October 23, 1923, approved a bond issue for power distribution. On March 11, 1924, it entered into a contract with the San Joaquin Light and Power Company under which the district agreed not to sell power outside of certain boundaries, and the company agreed to take the entire surplus power of the district, provided that the rate of delivery should be not less than 6500 kilowatts from June 1 to December 31, nor more than 2500 kilowatts from January 1 to May 31 of each year. The power company also agreed to take all future surplus output that might be developed by the district. In years in which the run-off of Tuolumne River is less than 1,900,000 acre-feet from January 1 to July 31, the district is not obligated to deliver to the company more than 65 per cent of its share of Don Pedro power. The price paid by the company to the district is 4.5 mills per kilowatt hour for energy delivered at the Livingston substation, at not less than 80 per cent load factor. The contract was to remain in force for fifteen years, but may be renewed at the option of the district for an additional fifteen years.

The Turlock Irrigation District includes an area of 181,498 acres between the Tuolumne and Merced rivers, of which 133,750 acres were irrigated in 1929. The Modesto Irrigation District contains a gross area of 81,183 acres on the north side of Tuolumne River, of which 66,372 acres were irrigated in 1929. The Waterford Irrigation District includes an area of 14,110 acres on the same side of the river and above the Modesto District, of which 5272 acres were irrigated in 1929. This district diverts through the Modesto Canal from LaGrange Dam but does not share in Don Pedro storage rights.

Water Supply—The water supply available for regulation is that allotted to the existing irrigation rights on the stream under the terms of the Raker Act (U. S. Congress 1913). Under these rights, the mean seasonal ultimate net run-off available for regulation at the Don Pedro site for the 40-year period, 1889–1929, would have been 1,634,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the proposed dam site, scale one inch equals 400 feet, was made by the State in 1925. The areas and capacities of reservoirs for various heights of dam, as set forth in Table 76, have been obtained up to elevation 650 feet from the contour map for the existing reservoir, scale one inch equals 500 feet, prepared by the Modesto and Turlock irrigation districts in 1913. For areas and capacities above that elevation, the U. S. G. S. topographic maps were used.

TABLE 76

AREAS AND CAPACITIES OF DON PEDRO RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
110	425	270	5,700
135	450	470	15,200
160	475	740	30,000
185	500	1,120	52,000
210	525	1,610	86,000
235	550	2,340	137,000
260	575	2,730	200,000
285	600	3,120	271,000
310	625	3,360	348,000
335	650	3,610	431,000
360	675	3,860	522,000
385	700	4,100	623,000
410	725	5,170	738,000
435	750	6,250	875,000
455	770	7,100	1,000,000
460	775	7,320	1,044,000
485	800	8,390	1,247,000
510	825	9,800	1,496,000
535	850	11,200	1,768,000
560	875	12,600	2,060,000
585	900	14,000	2,370,000

The capacity selected for the proposed Don Pedro Reservoir of 1,000,000 acre-feet is required to furnish a dependable irrigation supply to the lands which are or would be naturally dependent upon the Tuolumne River for such supply. The required supply could have been made available by a reservoir of this capacity during the 40-year period, 1889–1929, without resort to ground water storage, with an average seasonal deficiency of less than 2 per cent. With a flow line elevation of 770 feet, the reservoir basin would have a length of sixteen miles, an average width of nearly three-quarters of a mile and a submerged area of 7100 acres. Of the total submerged area, 3182 acres lie within the flow line of the existing reservoir at elevation 605.5 feet.

The present Don Pedro Reservoir floods the only lands that were of any appreciable extent and value for farming purposes below elevation 900 feet. A small area of bottom land along Woods Creek would be flooded by the proposed reservoir. The remaining area is practically all characteristic mountain land covered with scattering timber and brush, and used mostly for grazing. The Big Oak Flat road extending from Oakdale to the Yosemite Valley would be flooded from Woods Creek to where it crosses Moccasin Creek. The town of Jacksonville, consisting of about 20 frame houses, would be submerged. The Hetch Hetchy Railroad, built by the city of San Francisco from Hetch Hetchy Junction on the Sierra Railroad to the O'Shaughnessy Dam on the Tuolumne River, traverses the proposed reservoir site from about one-half mile below the mouth of Woods Creek to Moccasin Creek. The Mother Lode crosses areas that would be submerged and several gold mines and mining claims would be flooded. The Eagle-Shawmut, Tarantula, Clio-Vindicator and Harriman are the most important properties.

In irrigation yield studies of this reservoir, a net seasonal reservoir evaporation loss of 3.5 feet in depth on the reservoir surface has been used. The safe surface irrigation yield of the proposed reservoir for the 40-year period, 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per annum on the average and 35 per cent as a possible maximum in an exceptionally dry year such as 1924, would have been 1,330,000 acre-feet. The average seasonal irrigation yield for the 40-year period would have been 1,303,000 acre-feet. In obtaining this yield, ultimate diversions by the city of San Francisco for municipal purposes were deducted from the run-off of the Tuolumne River. These diversions were considered as being limited by the provisions of the "Raker Act" and the operation of the physical works proposed by the city for ultimate development, for an attempted draft of four hundred million gallons per day. Further details as to yield and utilization of water supplies developed by this reservoir are presented in Chapter VII.

Dam Site—A geological examination of the site of the present dam (See Appendix C) showed that the topographic conditions and geologic structure were not favorable for the construction of a higher dam at that site. However, at a point about one-half mile downstream from the present dam, there is a site which is favorable, both topographically and geologically, for a high dam. Here, a series of thick-bedded or banded rock formations resembling diabase strike across the stream. In order to best conform to the topography and the rock structure at this site, the center line of the dam has been located across the strike of the rock bands where these bands are relatively thick.

PLATE XXXVI

Present Don Pedro Dam Completed in 1922

Site of Proposed Dam Below Existing Structure

DON PEDRO DAM SITE ON TUOLUMNE RIVER

The stream bed and right abutment to the top of the cliff profile, 150 feet above stream bed, probably would require stripping to an average depth of 10 feet. From that point to the crest, an average depth of 20 feet probably would be required in order to remove loose joint blocks and reach reasonably sound rock in which the joints could be pressure grouted. The left abutment carries a heavier soil cover and is somewhat wooded. Stripping allowance should be 15 feet to an elevation of 150 feet above stream bed and 25 feet from this elevation to the crest of the ridge.

Dam and Appurtenances—The topography of the dam site and layout of the proposed dam and appurtenances are shown on Plate XXXVII, "Don Pedro Reservoir on Tuolumne River." The dam is a gravity type concrete structure, straight in plan and located at an an angle of about 20 degrees from normal to the axis of the stream bed. Its height above stream bed is 455 feet, including five feet of freeboard.

A spillway of the wing type, located at the left abutment of the dam, is controlled by 11 drum gates, 15 feet high by 50 feet long. The spillway channel is carried about 350 feet beyond the crest of the dam and past a bend in the canyon, so that the discharge would drop into the main stream channel about 1000 feet downstream from the dam.

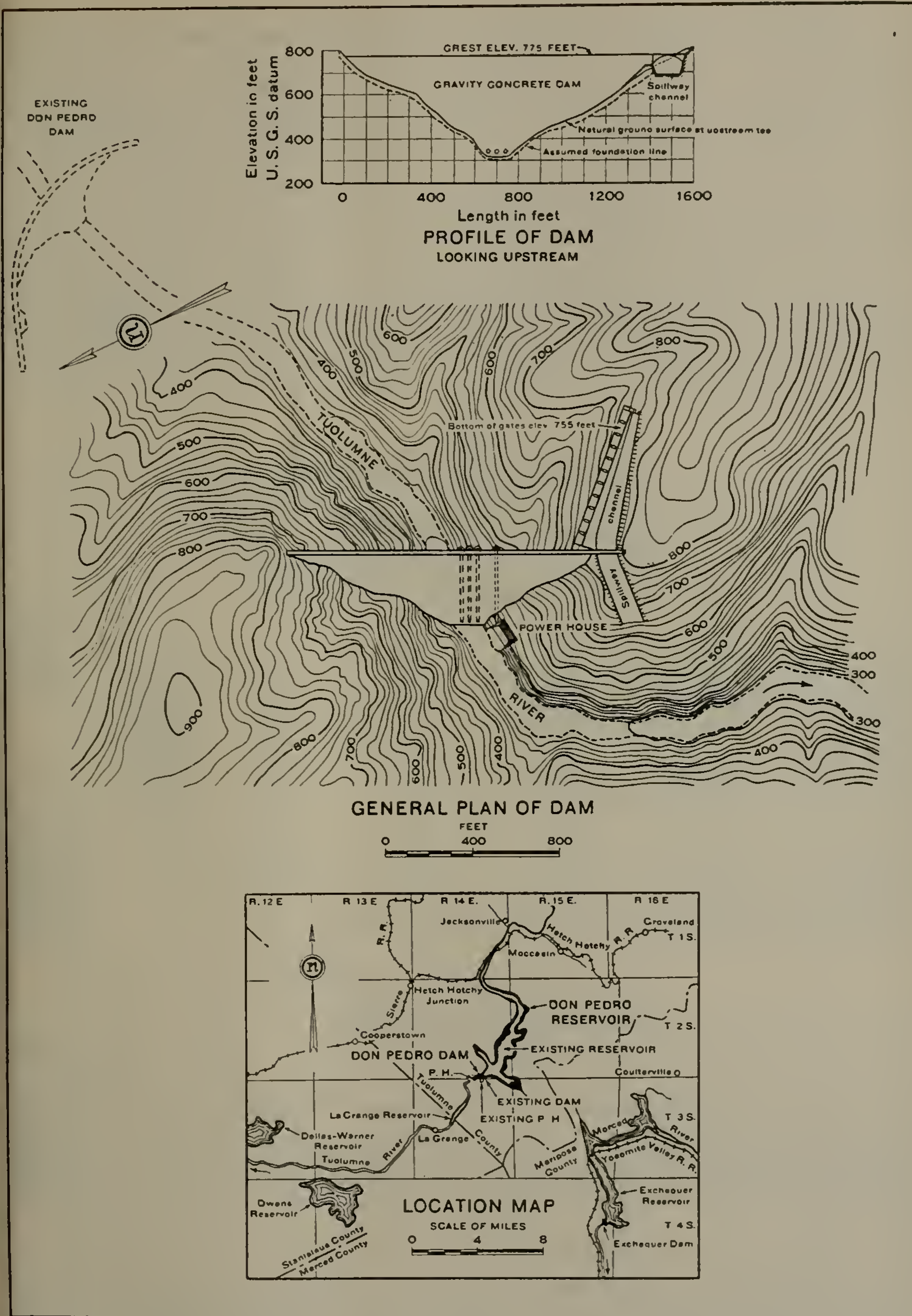
Reserve space of 214,000 acre-feet, involving a maximum drawdown of 32 feet, would be provided for regulation of the stream to a maximum flood flow of 15,000 second-feet, exceeded once in 100 years on the average. The required capacity for flood regulation is provided by the outlets for irrigation and power releases, assuming the power plant to be equipped with turbine by-passes.

The irrigation outlets consist of three 78-inch pipes through the dam, with a combined discharging capacity of 4000 second-feet under a minimum head of 50 feet. These outlets are controlled by needle valves and emergency slide gates. The inlets are at elevation 340 feet.

Power Plant—The economic size of installation for the proposed power plant has been determined as 120,000 kilovolt amperes, based on a value for power of $0.003 per kilowatt hour. The power plant is located on the right bank of the stream at the downstream toe of the dam. It would be supplied by steel penstocks through the dam, equipped with needle valves at the inlet of each turbine and emergency slide gates near the upstream face of the dam. The installation includes six 20,000 kilovolt ampere units equipped with turbine by-passes. It would replace the present Don Pedro Power Plant, which has an installed capacity of 33,740 kilovolt amperes.

Cost of Don Pedro Reservoir—The capital and annual costs of Don Pedro Reservoir and Power Plant, estimated in accord with bases previously presented in this chapter, are shown in Table 77. Estimates are also shown of revenue from sale of electric energy and the net annual cost after deducting power revenue. The tabulated costs do not include any amounts for the destruction of the present Don Pedro Reservoir and Power Plant of the Modesto and Turlock irrigation districts. It is contemplated that interests and lands now receiving service, both irrigation and power, from the present development would continue to receive the same service with no additional

PLATE XXXVII



DON PEDRO RESERVOIR

ON

TUOLUMNE RIVER

cost under the larger development as proposed herein for the State Water Plan. Therefore, in accord with such assumption, the commitments and obligations of the parties now interested in the present development would be maintained without modification. The figure for annual cost includes no amount for present development but does include amounts for equivalent service which would be rendered with the larger State proposal. It is not possible to foretell the conditions under which, or when or by whom, the proposed development would be constructed. Neither is it possible to state whether or not the present development would be entirely amortized and depreciated at the time the proposed development is undertaken. Therefore, the entire anticipated power revenue has been credited to the proposed unit and deducted from the gross annual cost to obtain the net annual cost.

TABLE 77

COST OF DON PEDRO RESERVOIR

Height of dam, 455 feet. Capacity of reservoir, 1,000,000 acre-feet.
Capacity of spillway, 120,000 second-feet.
Capacity of irrigation outlets, 4,000 second-feet.
Flood control outlet capacity of 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		65,000
Lands and improvements flooded and clearing		2,050,000
Excavation for dam, 272,000 cubic yards at $3.00 to $5.00	$856,000	
Mass concrete, 2,030,000 cubic yards at $7.20	14,616,000	
Reinforced concrete, 1,400 cubic yards at $18.00 to $45.00	40,000	
Spillway gates	220,000	
Spillway channel	1,430,000	
Irrigation outlets and sluiceways	282,000	
(Power outlets and controls included in cost of power plant)		
Drilling, grouting, drains and contraction seals	108,000	
		17,552,000
Miscellaneous		144,000
Subtotal		19,821,000
Administration and engineering at 10 per cent		1,982,000
Contingencies at 15 per cent		2,973,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,724,000
Total capital cost of dam and reservoir		26,500,000

Cost of Power Plant For Don Pedro Reservoir

Installed capacity, 120,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total cost of power plant, including all appurtenances	$6,000,000

Annual Cost of Don Pedro Reservoir and Power Plant

Gross annual cost of dam and reservoir	$1,590,000
Gross annual cost of power plant	484,000
Total gross annual cost	2,074,000
Average annual revenue from sale of electric energy, 365,000,000 kilowatt hours at $0.003	1,095,000
Average net annual cost not covered from sale of electric energy	979,000

Exchequer Reservoir on Merced River.

The Exchequer Reservoir is located in Townships 3 and 4 South, Ranges 15 and 16 East, M.D.B. and M., in Mariposa County about 20 miles northeast from the city of Merced. It is already developed by the Merced Irrigation District to a capacity of 279,000 acre-feet. It supplies water for lands in the district with a gross area of 189,682 acres, of which 134,379 acres were irrigated in 1929. The recently organized El Nido Irrigation District with a gross area of 9450 acres also obtains water from the Merced Irrigation District.

The drainage areas on the Merced River watershed, above the Exchequer Dam, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	52 square miles
Area between elevations 5000 and 10,000 feet	494 square miles
Area between elevations 2500 and 5000 feet	317 square miles
Area below elevation 2500 feet	171 square miles
Total area above Exchequer Dam	1034 square miles

A contour map of the dam site, for elevations above the existing dam, scale one inch equals 100 feet, was made by the State in 1925. The areas and capacities of reservoirs for various heights of dam, as set forth in Table 78, have been obtained up to elevation 750 feet from the contour map for this site, scale one inch equals 400 feet, prepared by J. D. Galloway in 1920. For areas and capacities above that elevation the U. S. G. S. topographic maps were used.

TABLE 78

AREAS AND CAPACITIES OF EXCHEQUER RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
102	500	240	6,500
127	525	440	15,500
152	550	690	30,500
177	575	950	51,000
202	600	1,190	79,000
227	625	1,460	112,000
252	650	1,750	153,000
277	675	2,090	202,000
302	700	2,470	262,000
*307	707	2,600	279,000
327	725	2,910	329,000
352	750	3,410	412,000
377	775	3,730	500,000
402	800	4,050	599,000
427	825	4,720	709,000
452	850	5,400	833,000
477	875	6,080	977,000
502	900	6,750	1,140,000

*Existing dam has only a 3-foot freeboard.

The present Exchequer Reservoir and Power Plant were constructed in 1925 by the Merced Irrigation District at a cost of $10,725,000. The dam is located below the mouth of Cotton Creek in the southwest quarter of Section 13, Township 4 South, Range 15 East, about seven miles upstream from the town of Merced Falls. It is a concrete gravity type dam, arched in plan with a constant radius of 674 feet on the upstream face. Its height is 307 feet above stream bed and it has a crest length of 960 feet. The reservoir, when filled to the flow line elevation of 707 feet, submerges an area of 2600 acres with a length of 13 miles and an average width of one-third of a mile. Two overflow spillways are provided—one at each end of the dam. The crest of each spillway, at elevation 693 feet, is 168 feet long and allows a depth of water of 14 feet to flow over the crests to concrete-lined channels excavated in solid rock and leading from the abutments. These spillways were designed for an estimated discharging capacity of 70,000 second-feet. The water level in the reservoir can be maintained at elevation 707 feet by means of 14 plate steel butterfly gates on the spillway crests. The power plant at the base of the dam has two

15,625 kilovolt ampere vertical turbo-generator units designed to operate under heads of from 140 to 300 feet. The units are supplied by steel penstocks, through the dam, 96 inches in diameter. The flow through each penstock is controlled by a needle valve at the turbine inlet. The penstocks also are equipped with emergency slide gates. Two sluice pipes, 60 inches in diameter, extend through the dam and past the power house walls. Each is provided with a regulating needle valve at the downstream end and an emergency slide valve above the needle valve.

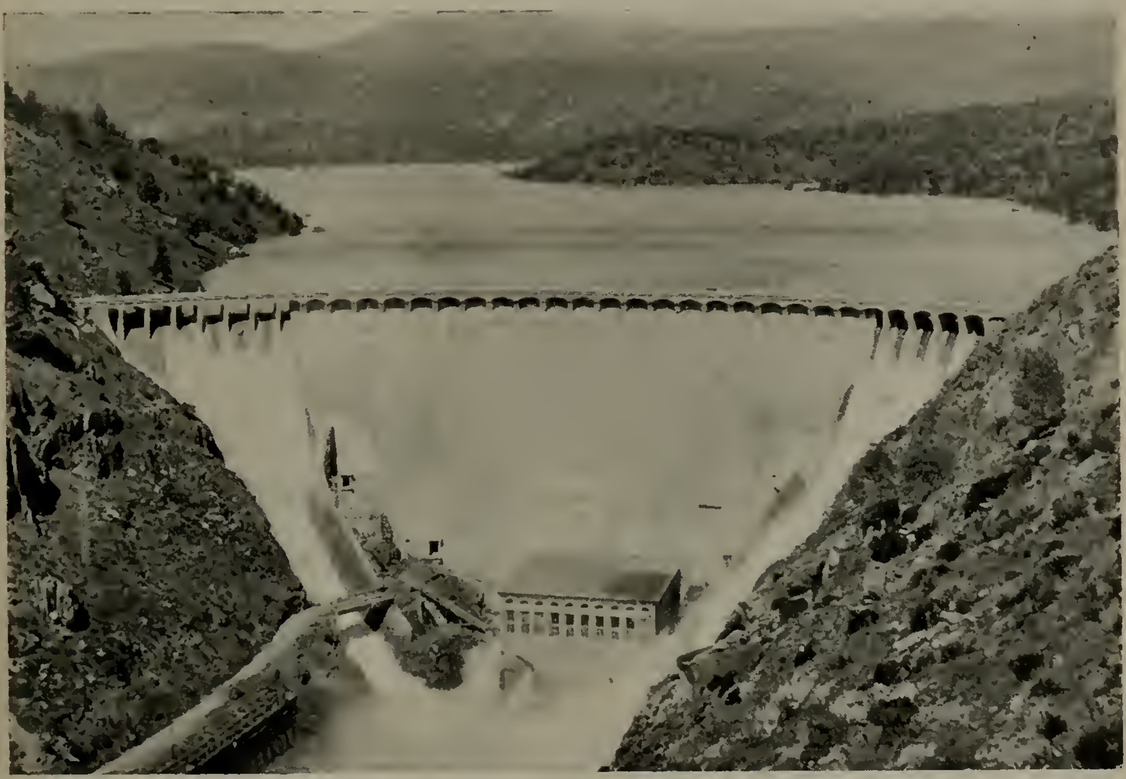
The Merced Irrigation District wholesales the power output to the San Joaquin Light and Power Company under a contract dated February 21, 1924, which runs for a period of 20 years with option to the district to continue for a second 20-year period. Power is delivered to the company at the Exchequer plant. Deliveries of water to the power plant are goverened chiefly by irrigation requirements, but the district agrees to deliver energy on a daily load factor ranging from unity to eight-tenths, as demanded by the company. The contract also provides for some delivery at less than eight-tenths daily load factor. The price paid by the power company is 4.5 mills per kilowatt-hour at the power plant switchboard.

There is no other reservoir site of adequate capacity on the stream and the dam site now occupied is the only one suitable for use in developing additional storage, which could be secured by increasing the height of the existing dam. A geological examination of the site (See Appendix C) reveals that so far as the foundation conditions are concerned such an increase in height would be possible. A study was made to determine the costs and additional yields obtainable by enlarging the present reservoir to various capacities up to 882,000 acre-feet. The relocation of the Yosemite Valley Railroad rendered the present development relatively expensive. The cost of this item alone was $5,566,000, or more than half the total cost of reservoir and power plant. With an additional increase in water surface elevation, the problem of relocation of this railroad would be even more difficult and costly. The geologic structure above the present dam on the right abutment would require excessive stripping from the crest of the present dam to the top of the ridge. These factors, together with the relatively small increase in yield which could be secured through additional storage, indicate that no increase in storage development can be economically justified.

Water Supply and Yield—The water supply available for regulation at this site under conditions of ultimate development would be the run-off of the Merced River impaired by such diversions above the reservoir as would be required for the ultimate development of all irrigable mountain and foothill lands dependent on the Merced River for their water supply. The mean seasonal ultimate net run-off for the 40-year period 1889–1929 would have been 989,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II. In making yield studies, a net seasonal reservoir evaporation loss of 3.5 feet in depth on the reservoir surface has been used.

The safe surface irrigation yield of the existing reservoir for the 40-year period 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per season on the average and 35 per cent as a possible maximum in an exceedingly dry year such as 1924, would have been 440,000 acre-feet. The average seasonal surface irrigation yield for the 40-year period would have been 434,000 acre-feet. In addition, an average seasonal supply of 294,000 acre-feet of reservoir spill would have been utilizable through ground water storage and pumping in absorptive areas. Further details pertaining to yield and utilization of water supply are presented in Chapter VII.

PLATE XXXVIII



EXCHEQUER DAM ON MERCED RIVER

Other Developments on Merced River—The only diversion of any importance from Merced River above the Exchequer Reservoir is that from Big Creek, a tributary of the South Fork of Merced River, to the Fresno River watershed for irrigation and lumbering purposes. The diversion ditch has a capacity of 35 second-feet, and the average seasonal exportation is estimated to be about 4600 acre-feet. Immediately below Yosemite Valley, the National Park Service has installed a power plant with a capacity of 2500 kilovolt amperes. The San Joaquin Light and Power Corporation has a small power plant, called the Mountain King, about two miles above the mouth of North Fork. It has an installed capacity of 350 kilovolt amperes. Below Merced Falls the same company has recently constructed a power plant with an installed capacity of 4000 kilovolt amperes.

Buchanan Reservoir on Chowchilla River.

The dam site for the Buchanan Reservoir on Chowchilla River is located in the southeast quarter of Section 22, Township 8 South, Range 18 East, M. D. B. and M., in Madera County, about 20 miles northerly from the city of Madera. There are no other reservoir sites of any importance on Chowchilla River.

The drainage areas on the Chowchilla River watershed, above the Buchanan dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	5 square miles
Area between elevations 2000 feet and 5000 feet	104 square miles
Area below elevation 2000 feet	129 square miles
Total area above Buchanan dam site	238 square miles

Water Supply—There is no existing or projected development of any consequence on the upper reaches of the stream. The water supply available for regulation at the Buchanan site would be the full natural run-off. The mean seasonal full natural run-off for the 40-year period, 1889 to 1929, is estimated as 70,900 acre-feet. Details of run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 400 feet, was prepared by C. M. Carter from a survey made in 1919. The State made a survey and prepared a contour map of the dam site, scale one inch equals 200 feet, in 1922. Table 79 sets forth areas and capacities for various heights of dam.

TABLE 79

AREAS AND CAPACITIES OF BUCHANAN RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
35	440	140	1,500
55	460	330	6,500
75	480	550	15,500
95	500	780	29,000
115	520	970	47,000
135	540	1,140	69,000
147	552	1,250	84,000
155	560	1,310	94,000

The reservoir basin is situated among rolling foothills, sparsely timbered and used chiefly for cattle range. Trial yield studies on this reservoir determined the season of maximum deficiency for the 40-year period 1889–1929 to be that of 1919–1920. The selected capacity of 84,000 acre-feet was found to be necessary to regulate the run-off without waste and to obtain the yield required to serve the tributary service area. At flow line elevation 552 feet, the flooded area would be 1250 acres, with a length of 3.5 miles and a maximum width of 1.2 miles. In making yield studies a net seasonal reservoir evaporation loss of 4.0 feet depth on the reservoir surface was used.

The safe surface irrigation yield of the proposed reservoir for the 40-year period 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per annum on the average and 35 per cent as a possible maximum in an exceptionally dry year, would have been 54,000 acre-feet. The mean seasonal irrigation yield for the 40-year period would have been 53,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

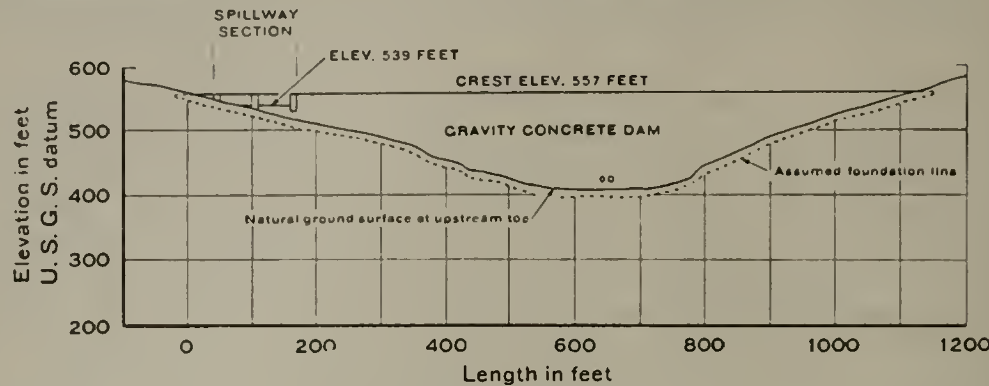
Dam Site—The Buchanan dam site is situated at a point where the Chowchilla River has cut its way through a rock ridge of mica schist in a direction across the planes of schistosity. A geological examination (see Appendix C) shows that the schistose texture is fully developed and makes up a hard crystalline rock mass, containing lines of weakness or parting planes which strike across the channel and dip north 35 degrees east, 75 to 80 degrees from the horizontal upstream. The site was partially excavated over 30 years ago, revealing the same bands of rock carrying from one abutment across the stream bed and up the opposing abutment. At fresh exposures in the stream bed, the schistosity planes and joints are closed features. The condition of these lines of weakness below ground surface is revealed by diamond drill borings made for the Madera Irrigation District. The planes and joints appear from the logs of the drill holes to be closed features, except in a limited zone from 45 to 60 feet below the stream bed where water was lost. The rock type is such as to contain no joint openings that could not be closed by pressure grouting. It is estimated that an average of ten feet of additional stripping would be required to secure a sound foundation.

Dam and Appurtenances—The topography at the site and the general layout of the proposed dam and appurtenances are shown on Plate XL, "Buchanan Reservoir on Chowchilla River." The dam is a concrete gravity type structure, straight in plan, 147 feet in maximum height above stream bed. An overflow type of spillway, located at the right abutment, is controlled by two drum gates 13 feet high by 50 feet long. The spillway has an estimated discharging capacity of 16,000 second-feet. Two 30-inch diameter pipes, with inlets at elevation 425 feet, are provided for release of irrigation supplies. These have a combined discharging capacity of 200 second-feet under a minimum head of 12 feet and are controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

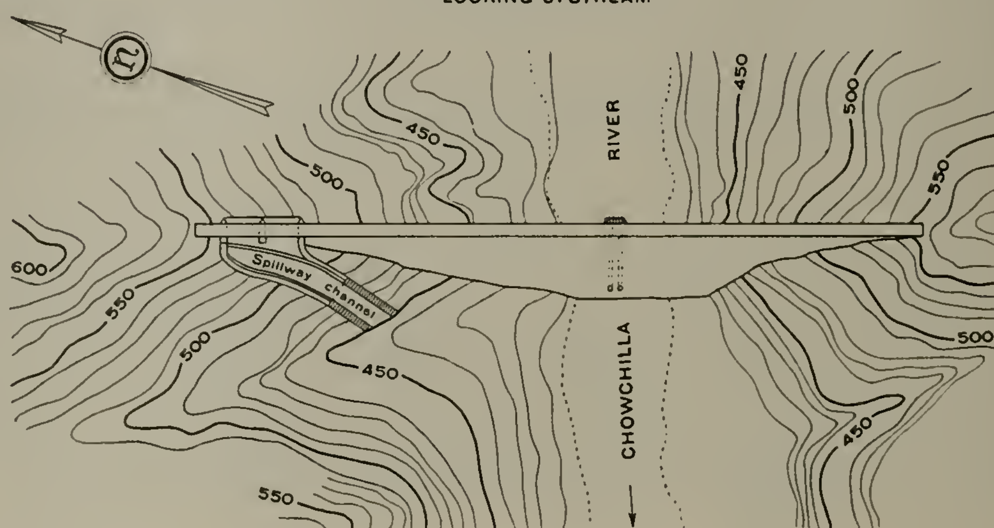
PLATE XXXIX

BUCHANAN DAM SITE ON CHOWCHILLA RIVER

PLATE XL

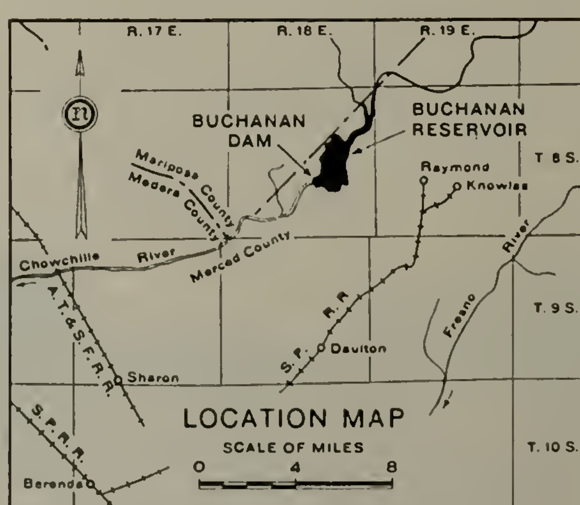


PROFILE OF DAM
LOOKING UPSTREAM



GENERAL PLAN OF DAM

FEET
0 200 400



BUCHANAN RESERVOIR

ON

CHOWCHILLA RIVER

Cost of Buchanan Reservoir—The capital and annual costs of Buchanan Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 80.

TABLE 80

COST OF BUCHANAN RESERVOIR

Height of dam, 147 feet. Capacity of reservoir, 84,000 acre-feet.
Capacity of spillway, 16,000 second-feet.
Capacity of irrigation outlets, 200 second-feet.

Exploration		$10,000
Diversion of river during construction		5,000
Lands and improvements flooded and clearing		125,000
Excavation for dam, 29,000 cubic yards at $4.50	$131,000	
Mass concrete, 178,000 cubic yards at $8.25	1,468,000	
Reinforced concrete, 1,000 cubic yards at $18.00 to $30.00	20,000	
Spillway gates	34,000	
Spillway channel	34,000	
Irrigation outlets and sluiceways	10,000	
Drilling, grouting, drains and contraction seals	30,000	
		1,727,000
Miscellaneous		77,000
Subtotal, dam and reservoir		1,944,000
Administration and engineering at 10 per cent		195,000
Contingencies at 15 per cent		292,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		169,000
Total capital cost of dam and reservoir		2,600,000
Total annual cost of dam and reservoir		$155,000

Windy Gap Reservoir on Fresno River.

The dam site for the Windy Gap Reservoir on Fresno River is located in the southeast quarter of Section 2, Township 7 South, Range 20 East, M.D.B. and M., in Madera County, about 32 miles northeasterly from the city of Madera. A lower site, called Hidden Reservoir, located near the valley floor, also was investigated, but its potential capacity was found to be inadequate for desired purposes.

The drainage areas on the Fresno River watershed, above the Windy Gap dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	14 square miles
Area between elevations 2000 and 5000 feet	88 square miles
Area below elevation 2000 feet	0
Total area above Windy Gap dam site	102 square miles

Water Supply—There is no existing or projected development of any consequence on the upper reaches of the stream. The water supply available for regulation at this site is the run-off of Fresno River, augmented by the importation of some water by ditches of the Madera Sugar Pine Lumber Company and Madera Canal and Irrigation Company from the adjacent drainage areas of the Merced and San Joaquin rivers. The mean seasonal run-off for the 40-year period, 1889–1929, is estimated as 55,200 acre-feet. Details of run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 1000 feet, and one of the dam site, scale one inch equals 200 feet, were prepared from surveys made by the State in August 1922. The areas and capacities set forth in Table 81 were obtained from a more detailed survey made by Madera Irrigation District in November 1922.

The critical period on the Fresno River covers the seasons from 1925 to 1929. The selected reservoir capacity of 62,000 acre-feet is the amount of storage that would have been required to regulate the water

TABLE 81

AREAS AND CAPACITIES OF WINDY GAP RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
85	1,960	110	2,500
105	1,980	180	5,000
125	2,000	290	10,000
145	2,020	430	17,000
165	2,040	600	27,500
185	2,060	830	42,000
205	2,080	1,100	60,500
206	2,081	1,110	62,000
225	2,100	1,440	86,000

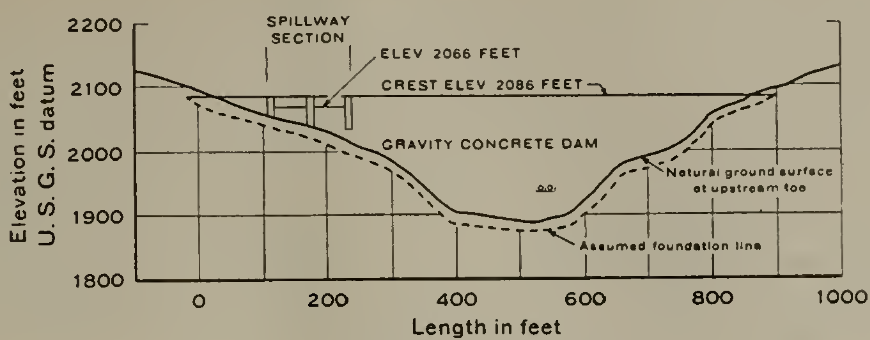
supply without waste for this period. With a flow line elevation of 2081 feet, the reservoir would flood an area of 1110 acres, with a length of four miles and a maximum width of 0.8 miles. The only improvements to be flooded are six miles of the Madera Sugar Pine Lumber Company's timber flume and four miles of county road, both of which would require relocation.

In making yield studies at this site, a net seasonal reservoir evaporation loss of 4.0 feet in depth in the reservoir was used. The safe surface irrigation yield of the proposed reservoir for the 40-year period, 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per season on the average and 35 per cent as a possible maximum in an exceedingly dry year, would have been 46,000 acre-feet. The mean seasonal yield for the 40-year period would have been 45,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

PLATE XLI

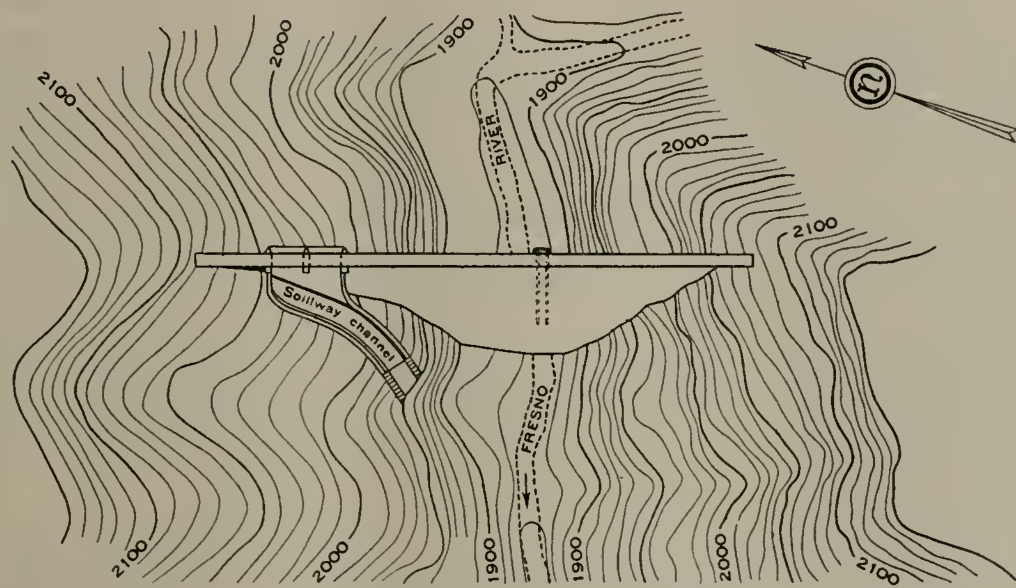
WINDY GAP DAM SITE ON FRESNO RIVER

PLATE XLII



PROFILE OF DAM

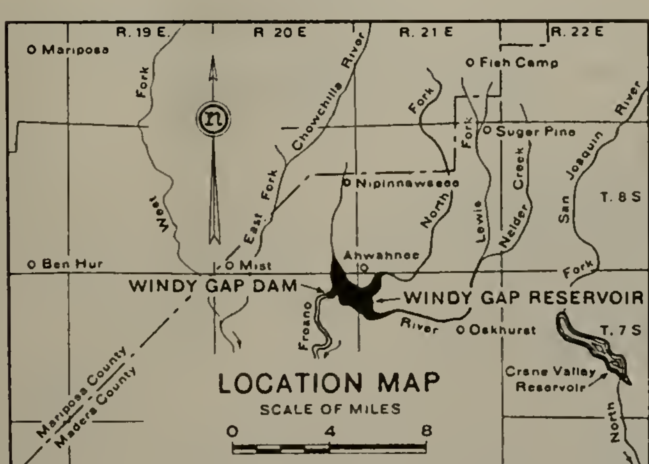
LOOKING UPSTREAM



GENERAL PLAN OF DAM

FEET

0 200 400



WINDY GAP RESERVOIR

ON

FRESNO RIVER

Dam Site—The Windy Gap dam site is located at the point where the Fresno River leaves Fresno Flats through a gorge cut across the topographically prominent Crook Mountain-Potter Ridge. The rock formation at this site comprises black micaceous slate, converted in part into a mica schist. The bands of rock strike across the stream bed continuously from the crest of one abutment to the other and dip nearly vertically. The joint planes are closed-tight features over fresh stream bed exposures and probably would refuse grout at relatively short distances below ground surface. It is estimated that an average depth of stripping of fifteen feet on the abutments would suffice to reach sound rock and that an average depth of ten feet of stripping would provide a sound rock foundation in the stream bed.

Dam and Appurtenances—The topography at the dam site and the general layout of the proposed dam and appurtenances are shown on Plate XLII, "Windy Gap Reservoir on Fresno River." The dam is a concrete gravity type structure, straight in plan, with a maximum height of 206 feet above stream bed. An overflow type of spillway, located at the right abutment, is controlled by two drum gates, 15 feet high and 50 feet long, and discharges through a lined channel about 200 feet long into a small draw that drains into the river about 150 feet below the toe of the dam. The discharging capacity of the spillway is estimated as 20,000 second-feet, or 4.3 times the once-in-25-year flood. Two 30-inch diameter pipes, with inlets at elevation 1940 feet, are provided for release of irrigation supplies. These have a combined discharging capacity of 200 second-feet under a minimum head of 12 feet, and are controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

Cost of Windy Gap Reservoir—The capital and annual costs of Windy Gap Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 82.

TABLE 82

COST OF WINDY GAP RESERVOIR

Height of dam, 206 feet. Capacity of reservoir, 62,000 acre-feet.
Capacity of spillway, 20,000 second-feet.
Capacity of irrigation outlets, 200 second-feet.

Exploration		$10,000
Diversion of river during construction		5,000
Lands and improvements flooded and clearing		265,000
Excavation for dam, 40,000 cubic yards at $1.00 to $5.00	$128,000	
Mass concrete, 225,000 cubic yards at $8.25	1,856,000	
Reinforced concrete, 800 cubic yards at $18.00 to $30.00	17,000	
Spillway gates	43,000	
Spillway channel	42,000	
Irrigation outlets and sluiceways	10,000	
Drilling, grouting, drains and contraction seals	28,000	
		2,124,000
Miscellaneous		64,000
Subtotal, dam and reservoir		2,468,000
Administration and engineering at 10 per cent		247,000
Contingencies at 15 per cent		370,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		215,000
Total capital cost of dam and reservoir		3,300,000
Total annual cost of dam and reservoir		$200,000

Friant Reservoir on San Joaquin River.

The dam site for the Friant Reservoir is located about one mile upstream from the town of Friant in the southwest quarter of Section 5, Township 11 South, Range 21 East, M. D. B. and M., at a stream bed elevation of 308 feet. It is situated in Fresno and Madera counties, about 20 miles east of the city of Madera and about 20 miles northerly from the city of Fresno.

In accord with the plan formulated, Friant Reservoir would provide primarily for the conservation and regulation of the tributary run-off of the San Joaquin River and the diversion of San Joaquin River water to the upper San Joaquin Valley to meet the needs therein of imported water supplies. San Joaquin River water now in use on lands in the lower San Joaquin Valley north of Mendota would be replaced by imported water supplies from the Sacramento River basin, conveyed to Mendota by the San Joaquin River pumping system. By means of this exchange, the imported water supplies required in the upper San Joaquin Valley would be furnished by gravity from San Joaquin River water instead of by pumping from the Sacramento River, thus saving about 300 feet in pumping head.

The drainage areas on the San Joaquin River watershed, above the Friant dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	297 square miles
Area between elevations 5000 and 10,000 feet	925 square miles
Area between elevations 2500 and 5000 feet	227 square miles
Area below elevation 2500 feet	182 square miles
Total area above Friant dam site	1631 square miles

Present Developments on San Joaquin River—Present developments on the San Joaquin River above Friant dam site are chiefly for hydroelectric power. The San Joaquin Light and Power Corporation and the Southern California Edison Company have developed four major storage reservoirs, with a combined capacity of about 334,000 acre-feet, for power regulation. The San Joaquin Light and Power Corporation has Crane Valley Reservoir on the North Fork with a capacity of 45,000 acre-feet. The regulated supply from this reservoir passes through a series of power plants, the last and largest of which is the Kerckhoff Plant on the main stream 17 miles above Friant. The Southern California Edison Company has Huntington Lake Reservoir on Big Creek, Florence Lake Reservoir on the South Fork and Shaver Lake Reservoir on Stevenson Creek, with storage capacities of 88,800, 64,400 and 135,300 acre-feet, respectively. Water from Florence Lake is diverted through a tunnel into Huntington Lake. Portions of the flows of Mono and Bear creeks also are delivered into this tunnel through a siphon across the South Fork. From Huntington Lake, the regulated flow may be utilized by the power plant known as Big Creek No. 1 and other plants below it, or it may be diverted to Shaver Lake through another tunnel. The regulated flow from Shaver Lake is utilized successively by the Big Creek Power Plants No. 2A, No. 8 and No. 3, and finally by the Kerckhoff Plant. Data on power storage developments and hydroelectric power plants on San Joaquin River are set forth in Tables 83 and 84, respectively.

TABLE 83

STORAGE RESERVOIRS FOR HYDROELECTRIC POWER DEVELOPMENT ON SAN JOAQUIN RIVER

Name of reservoir	Owner	Location	Height of dam, in feet	Capacity, in acre-feet
Crane Valley	San Joaquin Light and Power Co.	North Fork	145	45,000
Huntington Lake	Southern California Edison Co.	Big Creek	160	88,800
Florence Lake	Southern California Edison Co.	South Fork	162	64,400
Shaver Lake	Southern California Edison Co.	Stevenson Creek	171	135,300
Kerckhoff*	San Joaquin Light and Power Co.	Main river	106	4,200
Total				337,700

*For diversion purposes only.

TABLE 84

HYDROELECTRIC POWER PLANTS ON SAN JOAQUIN RIVER

Name of plant	Owner	Location	Installed capacity in kilovolt-amperes
Crane Valley	San Joaquin Light and Power Co.	North Fork	1,000
San Joaquin No. 3	San Joaquin Light and Power Co.	North Fork	3,750
San Joaquin No. 2	San Joaquin Light and Power Co.	North Fork	3,000
San Joaquin No. 1A	San Joaquin Light and Power Co.	Canal above main river	425
San Joaquin No. 1	San Joaquin Light and Power Co.	Main river	16,000
Kerckhoff	San Joaquin Light and Power Co.	Main river	42,600
Big Creek No. 1	Southern California Edison Co.	Big Creek	80,500
Big Creek No. 2A	Southern California Edison Co.	Big Creek	90,000
Big Creek No. 2	Southern California Edison Co.	Big Creek	70,000
Big Creek No. 8	Southern California Edison Co.	Big Creek	60,000
Big Creek No. 3	Southern California Edison Co.	Main river	84,000
Total			451,275

The Soquel Ditch belonging to the Madera Canal and Irrigation Company diverts water from the North Fork and releases it into Nelder Creek, a tributary of Fresno River. This ditch has a right to 50 second-feet when that amount is flowing in the stream. The average seasonal exportation is estimated to be about 5400 acre-feet. A discussion of present irrigation development and the status of existing water rights below Friant have been presented in Chapter IV.

Water Supply—The water supply available for regulation at the Friant site consists of the natural run-off of the San Joaquin River impaired by the operation of the up-stream developments previously discussed. The average seasonal ultimate net run-off for the 40-year period, 1889–1929, would have been 1,993,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Economic Considerations Governing the Selection of the Friant Site—In order to secure maximum economic regulation of the San Joaquin River and minimum interference with power uses on the upper reaches of the stream, a reservoir located near the valley floor is desirable. However, consideration of the rather unfavorable characteristics of the Friant dam site, which render storage development relatively expensive, namely, the shallow "U" shaped profile of the site, the great length of dam for the required height, and the necessity of having a dead storage volume of 130,000 acre-feet below the gravity diversion level required for serving the areas south of San Joaquin River, resulted in a careful investigation of the entire San Joaquin River to determine the possibility of securing a more economical storage and diversion development.

This investigation included the Temperance Flat dam site, six miles upstream from Friant, and topographic surveys and studies of other possible storage sites on the main San Joaquin River from its junction with Big Creek to several miles above the junction of the Middle and South forks. These surveys were mapped on a scale of one inch equals 400 feet. Consideration of these data and various geological reports eliminated from more detailed study all sites except Temperance Flat and Friant.

A contour map of the Friant Reservoir site, scale one inch equals 200 feet, was prepared from surveys made by Madera Irrigation District in 1921. A map of the dam site, scale one inch equals 100 feet, was prepared from these surveys and supplemental surveys made by the State in 1925. A contour map of the Temperance Flat Reservoir site, scale one inch equals 1000 feet, and one of the dam site, scale one inch equals 100 feet, were prepared from surveys made by the State in 1925 and 1930, respectively.

Table 85 sets forth areas and gross capacities for reservoirs with various heights of dam at the Friant site and Table 86 sets forth corresponding data for the Temperance Flat site.

TABLE 85

AREAS AND CAPACITIES OF FRIANT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Gross capacity of reservoir, in acre-feet
37	340	200	2,000
57	360	420	8,000
77	380	660	19,000
97	400	880	34,000
117	420	1,140	55,000
137	440	1,440	80,000
157	460	1,880	114,000
177	480	2,340	156,000
197	500	2,820	208,000
217	520	3,320	269,000
237	540	3,820	340,000
252	555	4,200	400,000
257	560	4,320	422,000
277	580	4,840	513,000
297	600	5,380	615,000
317	620	5,920	728,000
337	640	6,480	853,000

TABLE 86

AREAS AND CAPACITIES OF TEMPERANCE FLAT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
65	450	67	2,000
90	475	114	4,300
115	500	191	8,100
140	525	275	13,900
165	550	376	22,000
190	575	498	32,900
215	600	632	47,100
240	625	822	64,600
265	650	1,042	88,500
290	675	1,270	117,000
315	700	1,520	152,000
340	725	1,790	194,000
365	750	2,048	242,000
390	775	2,334	296,000
415	800	2,642	359,000
440	825	2,981	429,000
465	850	3,338	508,000
490	875	3,728	596,000
515	900	4,070	694,000
540	925	4,469	801,000
565	950	4,856	917,000
590	975	5,251	1,043,000
615	1,000	5,630	1,180,000

After making detailed cost estimates of various heights of dam at each site, comparisons were made of all economic factors of each reservoir for equal net capacities. The results are shown in Table 87 and graphically on Plate XLIII, "Economic Comparison of Friant and Temperance Flat Reservoirs on San Joaquin River." Both sites are situated at low elevations in the watershed area and are in a position to give maximum regulation of the stream flow. The water surface of the Temperance Flat Reservoir with a capacity of 100,000 acre-feet or over would interfere with the operation of the existing Kerckhoff Power Plant of the San Joaquin Light and Power Company.

Curve No. 1 on Plate XLIII shows the cost of rebuilding the Kerckhoff Power Plant plus the capitalized value of the loss in power output that would result from the operation of reservoirs of various capacities at the Temperance Flat site, based on a power value of $0.004 per kilowatt hour capitalized at 10 per cent. Curve No. 2 gives the total cost of Temperance Flat Dam and Reservoir for various capacities, including all lands and improvements flooded with the exception of Kerckhoff Power Plant. Curve No. 3 is the summation of corresponding values in curves No. 1 and No. 2, plus the cost of a 4500 second-foot capacity conveyance channel between Temperance Flat and Friant sites and a 1500 second-foot siphon across the San Joaquin River to connect with the Madera Canal. It shows the total cost of Temperance Flat Reservoir on a basis comparable with Friant, with the exception of credit for power which could be generated at the former site. Curve No. 4 was developed by adding, to corresponding values in Curve 3, the costs of developing sufficient dead storage to give equal capacities in the upper half (water depth) of Temperance Flat Reservoir, the costs of power plants installed for maximum effective heads and 3000 second-feet capacity, and the cost of reinforcing the outlet tunnel for power head, less the value of the power yield at $0.003 per kilowatt hour capitalized at 10 per cent. Curve No. 5 shows the cost

Net storage capacity, in acre-feet	Estimated cost of interference of Temperance Flat Reservoir with Kerckhoff Power Plant[1]	Estimated cost of Temperance Flat Reservoir	Net capital power credit (Value of power, (Col. 12) less total cost of power plant (Col. 10))	Net capital cost of Temperance Flat Reservoir and power plant (Values in Col. 4 less values in Col. 13)	Capital cost of Friant Reservoir	Net capital cost of Temperance Flat project in excess of Friant project
	(1)	(2)	(13)	(14)	(15)	(16)
1,000,000	$8,000,000	$38,200,000	$6,147,000	$50,453,000	--------------	--------------
900,000	8,000,000	34,100,000	5,802,000	46,398,000	--------------	--------------
800,000	8,000,000	30,100,000	5,480,000	42,220,000	--------------	--------------
700,000	7,900,000	26,300,000	5,045,000	38,055,000	$35,000,000	$3,055,000
600,000	7,600,000	22,600,000	4,620,000	33,880,000	29,500,000	4,380,000
500,000	7,000,000	19,000,000	4,136,000	29,764,000	24,400,000	5,364,000
400,000	6,200,000	15,500,000	3,577,000	25,623,000	19,600,000	6,023,000
300,000	5,000,000	12,100,000	2,953,000	21,347,000	15,200,000	6,147,000
200,000	3,600,000	9,000,000	2,308,000	16,892,000	11,300,000	5,592,000
100,000	1,600,000	6,100,000	1,499,000	12,101,000	7,800,000	4,301,000

[1] Includes cost of moving power plant plus ... ead 350 feet.
[2] Conduit comprises 4,500 linear feet of tu ... t of $5,000,000.
[3] This assumes dead storage in the lower ... velopment. Dead storage would amount to 20,000 and 120,000 acre-feet respectively for utilizable ne...
[4] Outlet elevation 480 feet.
[5] Capacity 3,000 second-feet; maximum e...
[6] Based on an overall plant efficiency of 7...

TABLE 86

AREAS AND CAPACITIES OF TEMPERANCE FLAT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
65	450	67	2,000
90	475	114	4,300
115	500	191	8,100
140	525	275	13,900
165	550	376	22,000
190	575	498	32,900
215	600	632	47,100
240	625	822	64,600
265	650	1,042	88,500
290	675	1,270	117,000
315	700	1,520	152,000
340	725	1,790	194,000
365	750	2,048	242,000
390	775	2,334	296,000
415	800	2,642	359,000
440	825	2,981	429,000
465	850	3,338	508,000
490	875	3,728	596,000
515	900	4,070	694,000
540	925	4,469	801,000
565	950	4,856	917,000
590	975	5,251	1,043,000
615	1,000	5,630	1,180,000

After making detailed cost estimates of various heights of dam at each site, comparisons were made of all economic factors of each reservoir for equal net capacities. The results are shown in Table 87 and graphically on Plate XLIII, "Economic Comparison of Friant and Temperance Flat Reservoirs on San Joaquin River." Both sites are situated at low elevations in the watershed area and are in a position to give maximum regulation of the stream flow. The water surface of the Temperance Flat Reservoir with a capacity of 100,000 acre-feet or over would interfere with the operation of the existing Kerckhoff Power Plant of the San Joaquin Light and Power Company.

Curve No. 1 on Plate XLIII shows the cost of rebuilding the Kerckhoff Power Plant plus the capitalized value of the loss in power output that would result from the operation of reservoirs of various capacities at the Temperance Flat site, based on a power value of $0.004 per kilowatt hour capitalized at 10 per cent. Curve No. 2 gives the total cost of Temperance Flat Dam and Reservoir for various capacities, including all lands and improvements flooded with the exception of Kerckhoff Power Plant. Curve No. 3 is the summation of corresponding values in curves No. 1 and No. 2, plus the cost of a 4500 second-foot capacity conveyance channel between Temperance Flat and Friant sites and a 1500 second-foot siphon across the San Joaquin River to connect with the Madera Canal. It shows the total cost of Temperance Flat Reservoir on a basis comparable with Friant, with the exception of credit for power which could be generated at the former site. Curve No. 4 was developed by adding, to corresponding values in Curve 3, the costs of developing sufficient dead storage to give equal capacities in the upper half (water depth) of Temperance Flat Reservoir, the costs of power plants installed for maximum effective heads and 3000 second-feet capacity, and the cost of reinforcing the outlet tunnel for power head, less the value of the power yield at $0.003 per kilowatt hour capitalized at 10 per cent. Curve No. 5 shows the cost

TABLE 87

ECONOMIC COMPARISON OF TEMPERANCE FLAT AND FRIANT RESERVOIRS

Net storage capacity, in acre-feet	Estimated cost of interference of Temperance Flat Reservoir with Kerckhoff Power Plant[1]	Estimated cost of Temperance Flat Reservoir	Combined cost of Temperance Flat Reservoir, interference with Kerckhoff power plant and a conduit from Temperance Flat reservoir to Friant dam site[2]	Cost for same items as column (3) but with utilizable storage in upper half-depth of reservoir[3]	Flow line elevations with utilizable storage in upper half-depth of reservoir, in feet	Temperance Flat Reservoir Power Plant								Net capital cost of Temperance Flat Reservoir and power plant (Values in Col. 4 less values in Col. 13)	Capital cost of Friant Reservoir	Net capital cost of Temperance Flat project in excess of Friant project
						Maximum power head, in feet[4]	Approximate average operating head, in feet	Cost of power plant, at $50 per kilovolt ampere[5]	Cost of putting outlet tunnel under pressure	Total cost of power plant and pressure outlet tunnel	Average seasonal water supply passing through power plant, in acre-feet	Value of power at $0.003 per kilowatt hour capitalized at 10 per cent[6]	Net capital power credit (Value of power, (Col. 12) less total cost of power plant (Col. 10))			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1,000,000	$8,000,000	$38,200,000	$51,200,000	$56,600,000	991	511	384	$6,898,000	$675,000	$7,573,000	1,550,000	$13,720,000	$6,147,000	$50,453,000	------------	------------
900,000	8,000,000	34,100,000	47,100,000	52,200,000	972	492	369	6,642,000	655,000	7,297,000	1,540,000	13,099,000	5,802,000	46,398,000	------------	------------
800,000	8,000,000	30,100,000	43,100,000	47,700,000	950	470	353	6,345,000	625,000	6,970,000	1,530,000	12,450,000	5,480,000	42,220,000	------------	------------
700,000	7,900,000	26,300,000	39,200,000	43,100,000	924	444	333	5,994,000	590,000	6,584,000	1,515,000	11,629,000	5,045,000	38,055,000	$35,000,000	$3,055,000
600,000	7,600,000	22,600,000	35,200,000	38,500,000	898	418	313	5,643,000	560,000	6,203,000	1,500,000	10,823,000	4,620,000	33,880,000	29,500,000	4,380,000
500,000	7,000,000	19,000,000	31,000,000	33,900,000	868	388	291	5,238,000	520,000	5,758,000	1,475,000	9,894,000	4,136,000	29,764,000	24,400,000	5,364,000
400,000	6,200,000	15,500,000	26,700,000	29,200,000	836	356	267	4,806,000	480,000	5,286,000	1,440,000	8,863,000	3,577,000	25,623,000	19,600,000	6,023,000
300,000	5,000,000	12,100,000	22,100,000	24,300,000	798	318	238	4,293,000	435,000	4,728,000	1,400,000	7,681,000	2,953,000	21,347,000	15,200,000	6,147,000
200,000	3,600,000	9,000,000	17,600,000	19,200,000	749	269	202	3,631,000	370,000	4,001,000	1,355,000	6,309,000	2,308,000	16,892,000	11,300,000	5,592,000
100,000	1,600,000	6,100,000	12,700,000	13,600,000	679	199	149	2,686,000	280,000	2,966,000	1,300,000	4,465,000	1,499,000	12,101,000	7,800,000	4,301,000

[1] Includes cost of moving power plant plus value of loss in power at $0.004 per kilowatt hour capitalized at 10 per cent. Low water level at present discharge, elevation 635 feet. Present total head 350 feet.

[2] Conduit comprises 4,500 linear feet of tunnel and 30,000 linear feet of open channel of 4,500 second feet capacity and siphon at Friant site of 1,500 second-feet capacity, with estimated cost of $5,000,000.

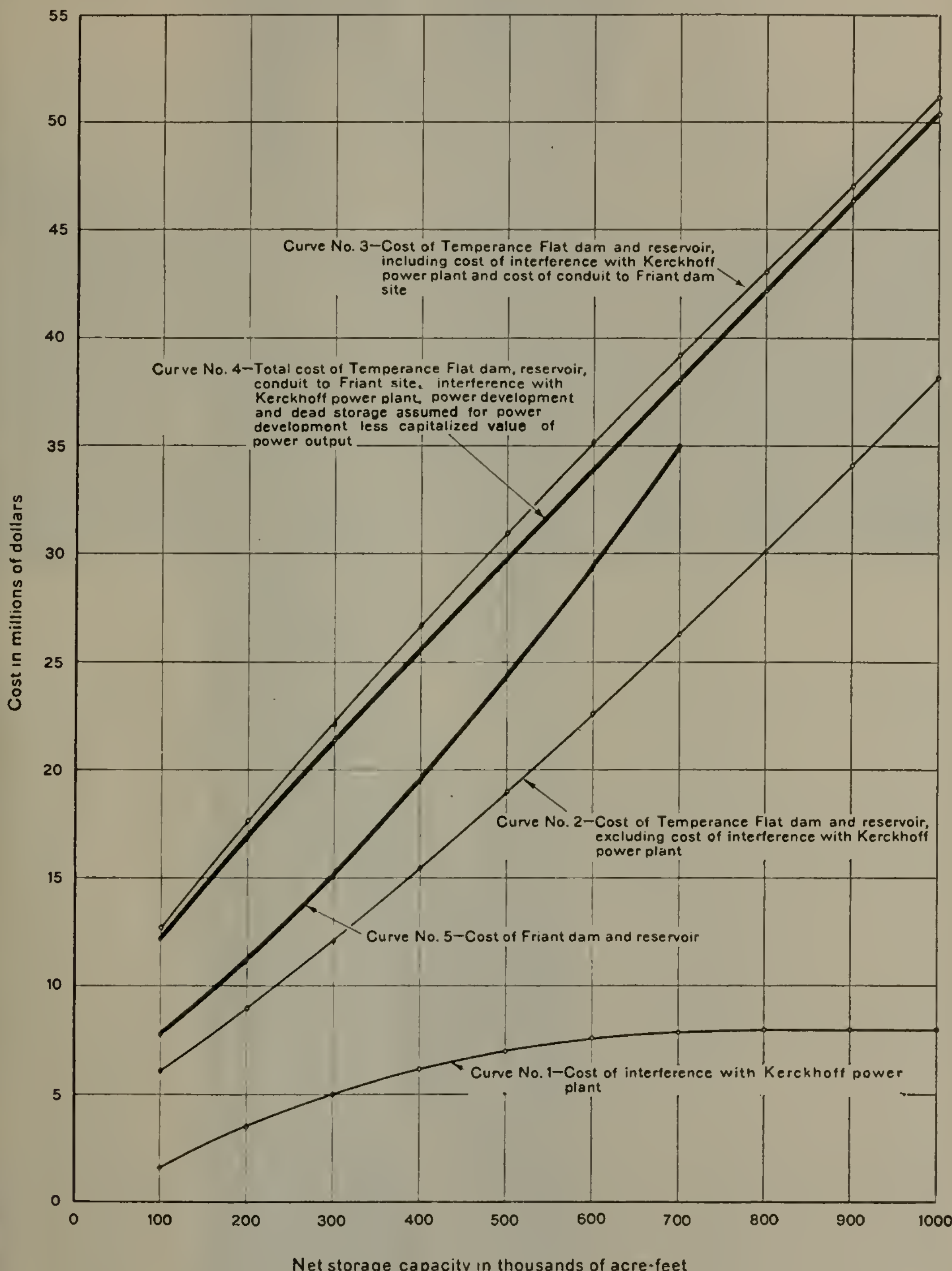
[3] This assumes dead storage in the lower half-depth of the reservoir with flow line elevations for full reservoir as in Col. (5), for the purpose of obtaining a greater net return from power development. Dead storage would amount to 20,000 and 120,000 acre-feet respectively for utilizable net storage capacities of 100,000 and 1,000,000 acre-feet.

[4] Outlet elevation 480 feet

[5] Capacity 3,000 second-feet; maximum efficiency 85 per cent; power factor 0.80.

[6] Based on an overall plant efficiency of 75 per cent.

PLATE XLIII



ECONOMIC COMPARISON

OF

FRIANT AND TEMPERANCE FLAT RESERVOIRS

ON

SAN JOAQUIN RIVER

PLATE XLIV

FRIANT DAM SITE ON SAN JOAQUIN RIVER

of Friant Reservoir with equivalent net storage capacities above the required diversion elevation. A comparison of curves No. 4 and No. 5 shows that, for any capacity below 700,000 acre-feet, the Friant Reservoir Project would be the more economical.

PLATE XLV

TEMPERANCE FLAT DAM SITE ON SAN JOAQUIN RIVER

Economic Capacities of Friant Reservoir and San Joaquin River-Kern County Canal for Ultimate Development—The function of Friant Reservoir in the ultimate development of the State Water Plan for the San Joaquin River basin is to furnish that portion of the water requirements within the areas on the east side of the upper San Joaquin Valley (included within hydrographic divisions Nos. 1, 2, 3, 4 and 6) which can not be met by the development of all local sources of supply. It is proposed to provide for the fullest practicable regulation of the available ultimate net run-off of the San Joaquin River in the Friant Reservoir and distribute the regulated supplies therefrom through conduits leading north and south from the reservoir. The storage capacity of Friant Reservoir, therefore, should be made sufficient to regulate the available run-off and furnish the water supplies at the rates and in the total amounts required.

The water supply required from Friant Reservoir for the ultimate development within Hydrographic Division No. 6 (Madera Unit) is fixed in accord with the assumed right of the proposed development of the Madera Irrigation District to acquire and divert a total seasonal water supply of 350,000 acre-feet. This water requirement also fixes the capacity of the proposed Madera Canal at 1500 second-feet. The water supply required from Friant Reservoir for the ultimate development of the remaining portion of the east side of the upper San Joaquin Valley to be served from this reservoir depends upon a determination of the amount of water that can be obtained from the fullest practicable development and utilization of the water supplies locally tributary thereto. This has involved a long and complicated analysis with a multiplicity of trial studies including analyses of surface and underground storage regulation and utilization. The results of these studies are presented hereafter in this chapter and in

Chapter VII. In order to arrive at the amount of water required from the San Joaquin River and the most desirable and economical degree of regulation at Friant Reservoir, it was necessary to consider the regulation and utilization of the local water supplies in combination with the supply to be obtained from Friant Reservoir. The studies show that a total average seasonal water supply of about 1,335,000 acre-feet from Friant Reservoir during the 40-year period, 1889–1929, would adequately satisfy the requirements for supplemental supply in the areas of deficiency.

The determination of the economic capacity of Friant Reservoir to furnish this water requirement for ultimate development of the upper San Joaquin Valley involves a consideration of cost of storage, cost of conveyance canals leading from the reservoir and cost of water supply utilization, to ascertain the minimum amount of these combined elements of cost of the water supply to be furnished. The capacity of the Madera Canal is fixed, as previously stated, by the delivery requirements for the Madera unit. However, the capacity the San Joaquin River-Kern County Canal, which is provided in the plan to convey water southerly from Friant Reservoir to the area on the east side of the San Joaquin Valley south of the San Joaquin River, is interrelated to and dependent upon the capacity of the reservoir. Equal yields could be obtained with varying amounts of reservoir and canal capacity operating in combination. It is necessary, therefore, to determine, for the yield required, the size of the reservoir and conduit which would result in the least combined cost. In addition, the cost of utilization by pumping from underground of supplies furnished from Friant Reservoir must be compared with the cost of providing storage to furnish surface irrigation supplies in the irrigation season, in lieu of pumping, to finally determine the minimum combined cost of storage, conveyance and utilization.

Studies pertaining to the determination of the minimum combined cost of Friant Reservoir storage and the San Joaquin River-Kern County Canal are presented in Table 88 and on Plate XLVI, "Curves of Equal Total Annual Cost and of Equal Mean Seasonal Yields for the Operation of Friant Reservoir and San Joaquin River-Kern County Canal for Various Capacities, 1889–1929." Table 88 shows the estimated annual cost for the canal with various capacities, the average seasonal yield in acre-feet for different combinations of reservoir and canal capacity and the estimated combined annual cost of canal and reservoir for different combinations of canal and reservoir capacity, based on the available run-off for the 40-year period, 1889–1929. The estimated reservoir yields are based upon the assumption that surface storage would be provided only as required to permit of maximum utilization of the water supplies furnished to the areas served through the combined means of surface irrigation and ground water storage and pumping. The storage capacities shown in Table 88 are those required to furnish the water supply for the Madera unit as well as the area south of the San Joaquin River. However, the yields shown in the table for various storage capacities are those for the area south of the San Joaquin River only. Plate XLVI has been compiled from the data presented in Table 88. The combinations of reservoir and canal capacities for various yields which would result in obtaining the

TABLE 88

COMBINED ANNUAL COSTS OF FRIANT RESERVOIR AND SAN JOAQUIN RIVER-KERN COUNTY CANAL FOR VARIOUS CAPACITIES WITH AVERAGE SEASONAL YIELDS FOR THE 40-YEAR PERIOD, 1889-1929, FOR AREAS SOUTH OF SAN JOAQUIN RIVER

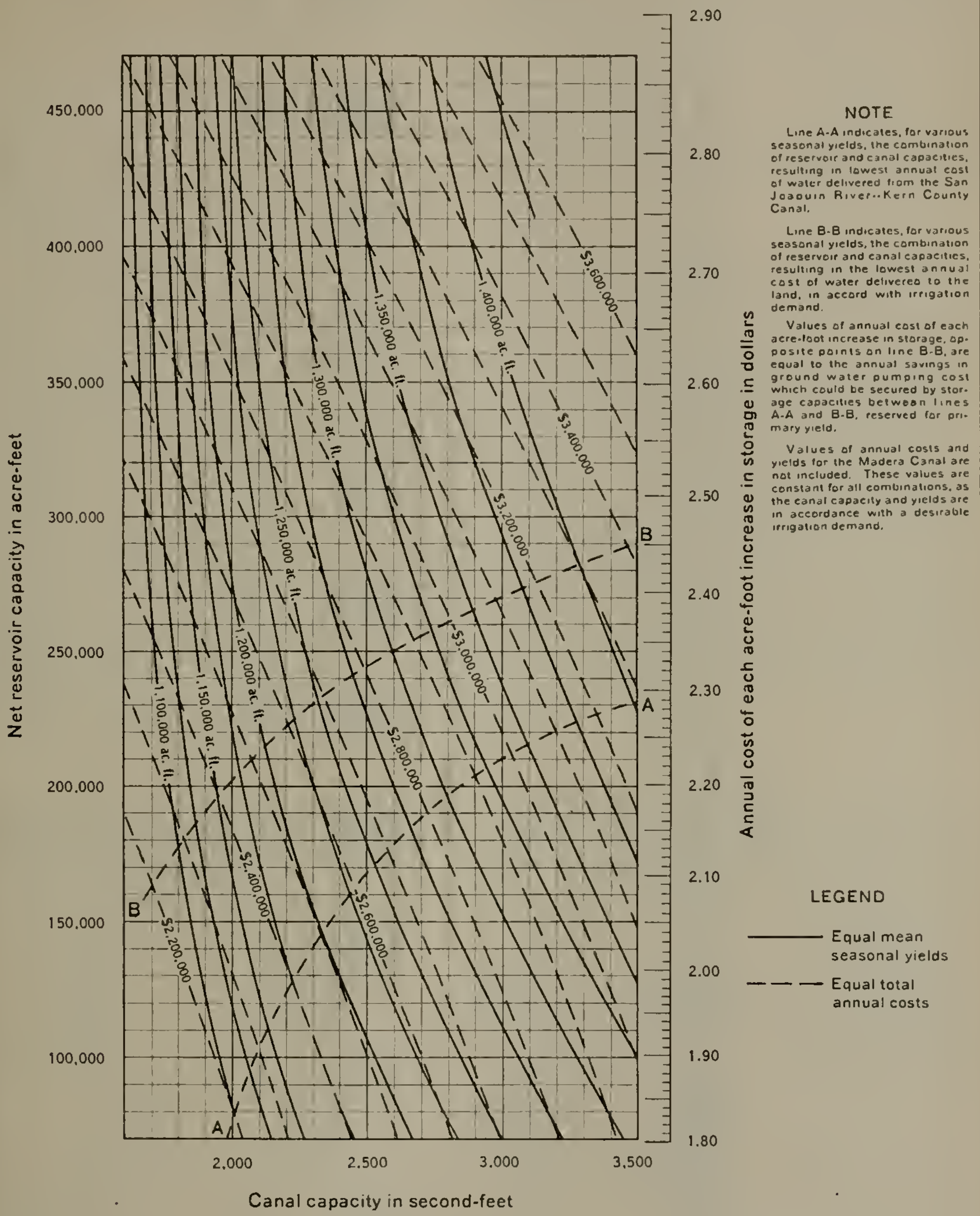
Utilizable storage capacity of reservoir, in acre-feet	Annual cost of reservoir	Canal capacity, 2,000 second-feet. Annual cost of canal, $1,760,000		Canal capacity, 2,500 second-feet. Annual cost of canal, $2,021,000		Canal capacity, 3,000 second-feet. Annual cost of canal, $2,281,000		Canal capacity, 3,500 second-feet. Annual cost of canal $2,535,000,	
		Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir	Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir	Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir	Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir
0	$300,000	--------	$2,060,000	--------	$2,321,000	--------	$2,581,000	--------	$2,835,000
50,000	385,000	1,075,000	2,145,000	1,175,000	2,406,000	1,245,000	2,666,000	1,295,000	2,920,000
100,000	475,000	1,115,000	2,235,000	1,200,000	2,496,000	1,270,000	2,756,000	1,325,000	3,010,000
150,000	574,000	1,140,000	2,334,000	1,230,000	2,595,000	1,300,000	2,855,000	1,360,000	3,109,000
200,000	678,000	1,165,000	2,438,000	1,260,000	2,699,000	1,330,000	2,959,000	1,385,000	3,213,000
250,000	793,000	1,185,000	2,553,000	1,285,000	2,814,000	1,355,000	3,074,000	1,410,000	3,328,000
300,000	911,000	1,205,000	2,671,000	1,310,000	2,932,000	1,375,000	3,192,000	--------	3,446,000
350,000	1,040,000	1,220,000	2,800,000	1,330,000	3,061,000	1,395,000	3,321,000	--------	3,575,000
400,000	1,170,000	1,230,000	2,930,000	1,350,000	3,191,000	1,410,000	3,451,000	--------	3,705,000
450,000	1,310,000	1,240,000	3,070,000	1,360,000	3,331,000	1,425,000	3,591,000	--------	3,845,000

minimum combined annual costs are indicated on Plate XLVI by the dotted curve designated "A-A". For the required average seasonal yield of 1,335,000 acre-feet for the area south of the San Joaquin River, the most economical combination would be a reservoir capacity of 210,000 acre-feet and a canal capacity of 3000 second-feet.

The total average seasonal yield of 1,335,000 acre-feet, obtainable from Friant Reservoir with a capacity of 210,000 acre-feet, for use in the area south of the San Joaquin River would be furnished in part during the irrigation season to directly meet the irrigation demands and in part outside of the irrigation season. The portions of the total supply so delivered are designated, respectively, "in-season" water and "out-of-season" water. "Out-of-season" water would be stored underground and its utilization would require pumping. Consideration has been given to the cost of utilizing by pumping such "out-of-season" water as compared to the cost of providing additional storage in Friant Reservoir to furnish a greater amount of "in-season" water for a surface irrigation supply in place of a pumped supply. The economic limit of additional storage to provide a greater amount of "in-season" water would be arrived at when the annual cost of such additional storage becomes equal to the cost of pumping an equivalent supply from underground. In making this economic study, pumping costs have been segregated into charges for, first, operation and energy estimated at three cents per foot acre-foot of water pumped, and, second, interest and other fixed charges estimated at two cents per foot acre-foot of water pumped. Operation and energy charges are based upon average pumping lifts and the average amount of water pumped over the period considered. However, interest and fixed charges are based upon the required maximum installed pumping capacity which would be fixed by the maximum pumping lift and the maximum amount of water to be pumped in a season of minimum yield such as 1923–1924. For the period 1889–1929 considered, it has been conservatively assumed that the maximum pumping lift, including draw-down, would have been 75 feet and that the average pumping lift, including draw-down, would have been 45 feet.

Table 89 sets forth additional average seasonal yields of "in-season" water that could have been secured during various periods with an assumed additional reservoir capacity of 100,000 acre-feet. The data are compiled for various combinations of reservoir and canal capacities. The net reservoir capacity, exclusive of the additional storage provided for additional "in-season" water, is shown at the head of the columns and the total reservoir capacity, including additional storage for "in-season" water, is shown at the bottom of the columns. The data in this table are presented chiefly for the purpose of showing the effect of additional storage upon the volume of "in-season" water supply obtainable. The data show that the yield of "in-season" water obtained in per cent of the additional storage provided for this purpose varies considerably for different combinations of reservoir and canal capacity and for the different periods of run-off considered. The additional amount of "in-season" water for a given storage capacity increases with greater canal capacity, and, for a given canal capacity, decreases with larger reservoir capacity.

PLATE XLVI



CURVES OF EQUAL TOTAL ANNUAL COSTS
AND OF
EQUAL MEAN SEASONAL YIELDS
FOR THE OPERATION OF
FRIANT RESERVOIR
AND
SAN JOAQUIN RIVER--KERN COUNTY CANAL
1889--1929

TABLE 89

AVERAGE SEASONAL QUANTITIES OF IRRIGATION SUPPLY TRANSFERABLE FROM "OUT-OF-SEASON" TO "IN-SEASON" DELIVERY BY AN ADDITIONAL STORAGE CAPACITY OF 100,000 ACRE-FEET IN FRIANT RESERVOIR

Capacity of San Joaquin River-Kern County Canal, in second-feet	3,500		3,000				2,500			2,000	
Net reservoir capacity, exclusive of additional storage, in acre-feet	75,000	170,000	75,000	170,000	270,000	370,000	75,000	170,000	270,000	75,000	170,000
Period	Average seasonal increase of in-season water, in acre-feet										
1889–1929	91,000	74,000	84,100	59,200	51,500	48,800	72,200	45,200	35,500	49,300	26,400
1909–1929	91,800	77,500	87,400	64,900	58,000	55,000	78,100	51,800	44,600	58,400	32,000
1917–1929	92,900	91,100	91,100	81,600	76,000	72,300	89,700	70,100	60,600	72,600	38,900
1922–1929	89,800	85,800	89,900	79,000	72,000	68,600	87,700	65,400	57,600	66,100	45,800
Total reservoir capacity, including additional storage for increasing in-season water, in acre-feet	175,000	270,000	175,000	270,000	370,000	470,000	175,000	270,000	370,000	175,000	270,000

The period, 1917–1929, shows the largest amounts of additional "in-season" water as related to the additional storage. In a season of minimum run-off such as 1923–1924, the studies show that the increased amount of "in-season" water obtainable would be practically equal to the additional storage capacity provided up to 100,000 acre-feet or more. It should be noted that the provision of additional storage capacity for the purpose of obtaining an increased amount of "in-season" water would not appreciably increase the total seasonal reservoir yield.

The data on the permissible economic increase in storage capacity (above the economic storage capacity shown by Curve "A-A" on Plate XLVI), for providing additional "in-season" water to furnish a surface irrigation supply in place of "out-of-season" supplies requiring ground water storage and pumping are presented in Table 90. Starting with the economic reservoir and canal capacities as shown by curve "A-A" on Plate XLVI, trial studies were made using different amounts of additional reservoir capacity for obtaining increased amounts of "in-season" water and comparative estimates made of cost of additional storage and savings that would be effected in pumping costs. The economic additional storage capacities shown in Table 90 are those for which a balance was reached between cost of additional storage and the saving in pumping cost effected by the substitution for a pumped supply of the "in-season" surface irrigation supply obtained from the additional storage.

TABLE 90

ECONOMIC INCREASE OF STORAGE CAPACITY IN FRIANT RESERVOIR FOR PROVIDING ADDITIONAL "IN-SEASON" SURFACE IRRIGATION SUPPLIES IN PLACE OF "OUT-OF-SEASON" SUPPLIES REQUIRING GROUND WATER STORAGE AND PUMPING

San Joaquin River-Kern County Canal capacity, in second-feet	Economic net reservoir capacity exclusive of additional storage, in acre-feet	Economic additional storage capacity, in acre-feet	Total net storage capacity, in acre-feet	Average seasonal increase of in-season water for 40-year period 1889-1929, in per cent of additional storage capacity
2,000	80,000	120,000	200,000	47
2,500	170,000	75,000	245,000	55
3,000	210,000	60,000	270,000	60
3,500	230,000	60,000	290,000	64

To illustrate the method of determining the economic additional storage capacities shown in Table 90, the following example is presented:

With a canal capacity of 3000 second-feet and an economic net reservoir capacity of 210,000 acre-feet as shown by Curve "A-A" on Plate XLVI, an additional storage capacity of 60,000 acre-feet reserved for providing additional "in-season" water would have resulted in an average increase of 36,000 acre-feet of "in-season" water during the 40-year period, 1889–1929. The additional average yield of "in-season" water is 60 per cent of the additional storage capacity provided for this purpose. In a season of minimum run-off such as 1923–1924, the additional amount of "in-season" water obtained would have been 60,000 acre-feet or 100 per cent of the additional storage provided. As shown on Plate XLVI, the average annual cost per acre-foot of the additional 60,000 acre-feet of storage capactiy is $2.31.

The saving which would be effected in pumping cost is estimated as follows: Interest and fixed charges would be based upon the maximum required pumping installation to furnish a water supply equivalent in amount to that provided by the additional storage capacity in a season of minimum run-off such as 1923–1924. On this basis the cost per acre-foot for interest and fixed charges on pumping, with an estimated maximum lift of 75 feet and a volume of pumping equal to 100 per cent of the additional storage capacity provided, would be $1.50 ($0.02×75×100%). Operation and energy charges would be based upon an average estimated pumping lift of 45 feet and an average volume of water pumped during the 40-year period of 60 per cent of the additional storage capacity provided. On this basis operation and energy charges would amount to $0.81 ($0.03×45×60%). The total annual cost per acre-foot which would be saved in pumping costs would, therefore, be $2.31, or an amount equal to the cost per acre-foot of additional storage capacity to provide the substitute "in-season" surface irrigation supply. A further additional storage of 30,000 acre-feet would increase the average amount of "in-season" water by 50 per cent of such additional storage. The average annual cost of an additional 30,000 acre-feet of storage, as shown by Plate XLVI, would be about $2.44 per acre-foot. The saving in pumping cost by the substitution of the surface irrigation supply obtained thereby would be but $2.18 per acre-foot. Hence, any further additional storage capacity in excess of 60,000 acre-feet to provide additional "in-season" water would result in a greater annual cost for storage than the saving in pumping cost that could be effected. The additional economic storage capacities for other combinations of canal and reservoir capacity have been estimated similarly.

Based upon the data presented in Table 90, the dotted curve, designated as "B-B," has been plotted on Plate XLVI. The points on this curve show the approximate economic capacity of Friant Reservoir for different capacities of the San Joaquin River-Kern County Canal, based upon obtaining the most economical combination of all elements of cost, including storage, conveyance and water supply utilization. Since the total seasonal yield is not materially increased by the additional storage provided for increasing the amount of "in-season" water, the seasonal yields, for the combination of reservoir and canal capacities indicated by curve "B-B," are shown for particular canal capacities by the points of intersection of curve "A-A" with the yield curves. Based on the required yield of Friant Reservoir to furnish the ultimate requirements for an imported water supply to the area on the east side of the upper San Joaquin Valley south of the San Joaquin River, it is finally concluded that the most desirable and economic capacities for Friant Reservoir and the San Joaquin River-Kern County Canal would be 270,000 acre-feet and 3000 second-feet respectively. This required reservoir capacity would be above the required diversion level of the San Joaquin River-Kern County Canal below which there would be a dead storage of 130,000 acre-feet. The required gross storage capacity of Friant Reservoir would, therefore be 400,000 acre-feet, with a net utilizable storage of 270,000 acre-feet

Based upon the adopted canal capacities of 3000 second-feet for the San Joaquin River-Kern County Canal and 1500 second-feet for the Madera Canal, the cost of storage and seasonal yield for various reservoir capacities is shown on Plate XLVII, "Cost of Reservoir Capacity and Unit Yield of Water for Irrigation from Friant Reservoir."

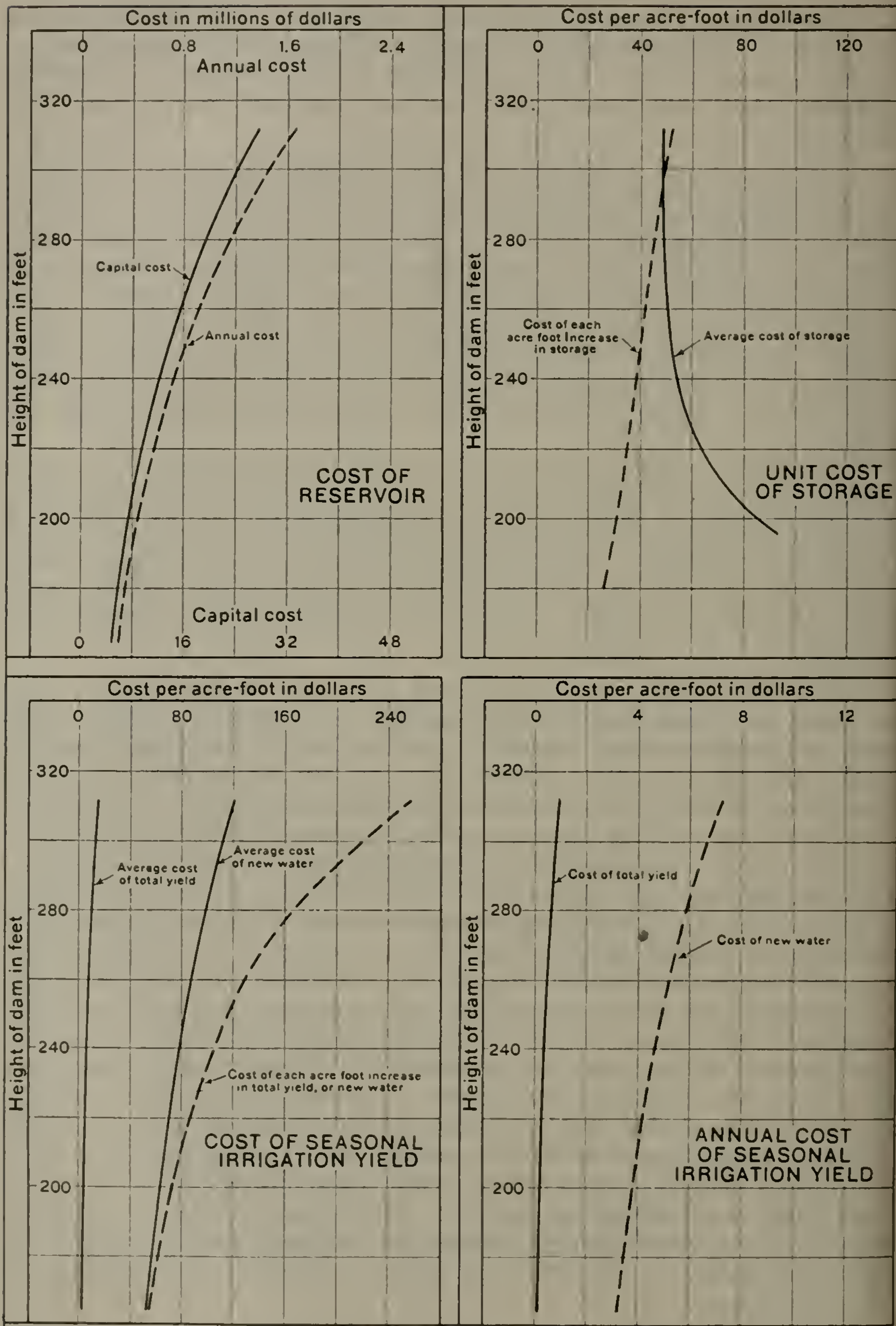
Reservoir Site and Yield—The Friant Reservoir site is situated in the low mountain or foothill area just above the point where the San Joaquin River has cut its channel into the eastern rim of the valley floor. The bottom of the reservoir basin around the site of the former town of Millerton is open. The side slopes further upstream are covered with brush and a few pine trees. The area is used for cattle range. At the flow line elevation of 555 feet for a gross storage capacity of 400,000 acre-feet, the reservoir would flood an area of 4200 acres having a length of six miles and a maximum width of about two miles.

In making yield studies at this site, a net seasonal reservoir evaporation loss of 4.0 feet in depth on the reservoir surface was used. For the 40-year period, 1889–1929, the operation of this reservoir in conjunction with ground water storage in the upper San Joaquin Valley would have resulted in an average irrigation yield of 1,726,000 acre-feet. Details of reservoir yields and utilization are presented in Chapter VII.

Dam Site—The dam site, located about one mile upstream from the town of Friant, has a rather shallow "U" shaped profile so that with the height of dam proposed, 252 feet above the stream bed, the total crest length would be 3800 feet. A geological examination was made of river channel and slopes from Friant upstream to Temperance Flat dam site and the general geology together with the results of detailed examinations of Friant, Fort Millerton and Temperance Flat sites are presented in Appendix C. The Friant site occupies an area of complex metamorphic rocks which have been given the general name, mica schist. Sound rock is found at the surface in the streambed and at moderate depths below the side slope surface. The Madera Irrigation District has explored the site with test pits and diamond drill holes and examination of test pits and analyses of cores reveal the character of the bed rock to be entirely satisfactory as a foundation for a concrete structure as proposed. It is estimated that the sound rock should be found at a depth of about 25 feet measured at right angles to the slope on the left abutment. An average depth of stripping of 40 feet may be required on the right abutment, as a portion of it contains an old stream terrace. The estimated stripping requirements in the stream bed vary from eight to fifteen feet in depth. The estimated depths of stripping are shown graphically in Appendix C of this report.

Dam and Appurtenances—The topography of the site and the general layout of the proposed dam and appurtenances are shown on Plate XLVIII, "Friant Reservoir on San Joaquin River." The dam is a concrete gravity type structure, straight in plan across the stream

PLATE XLVII



COST OF RESERVOIR CAPACITY AND UNIT YIELD OF WATER FOR IRRIGATION FROM FRIANT RESERVOIR

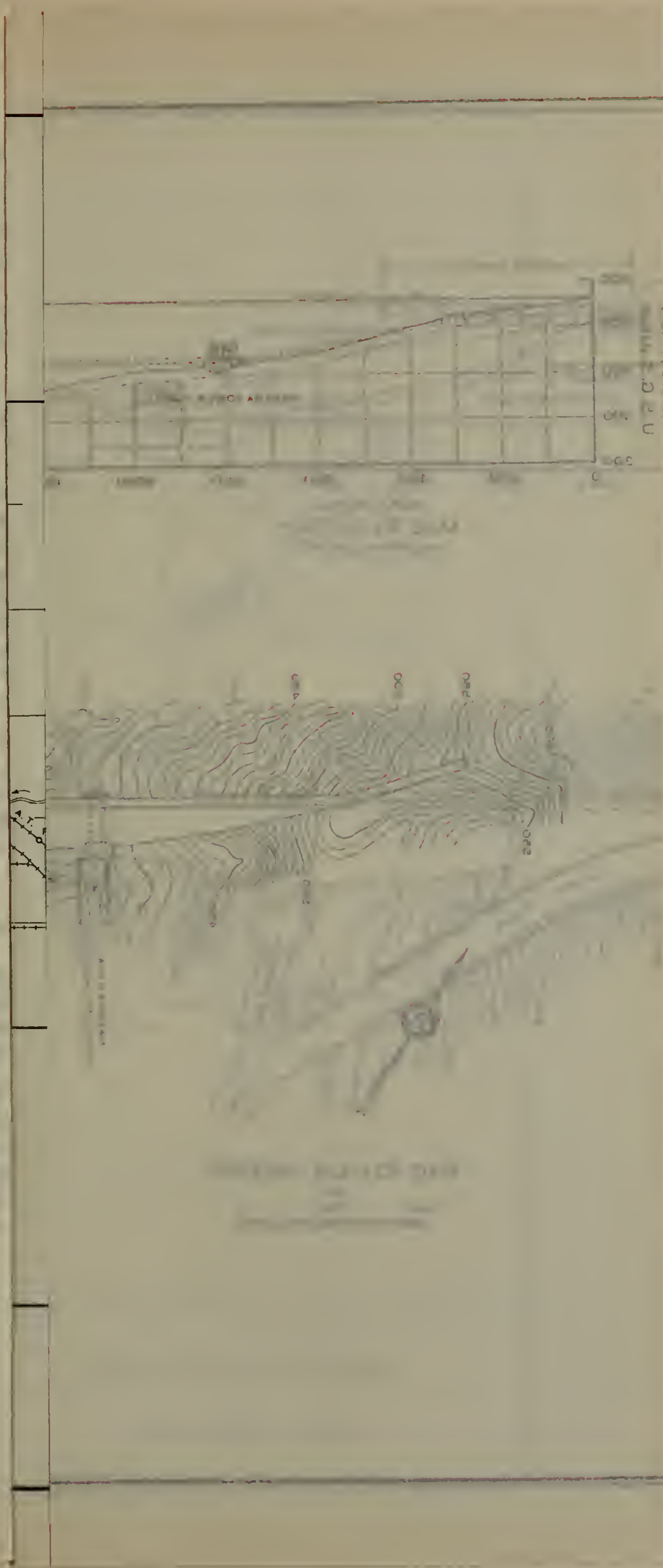
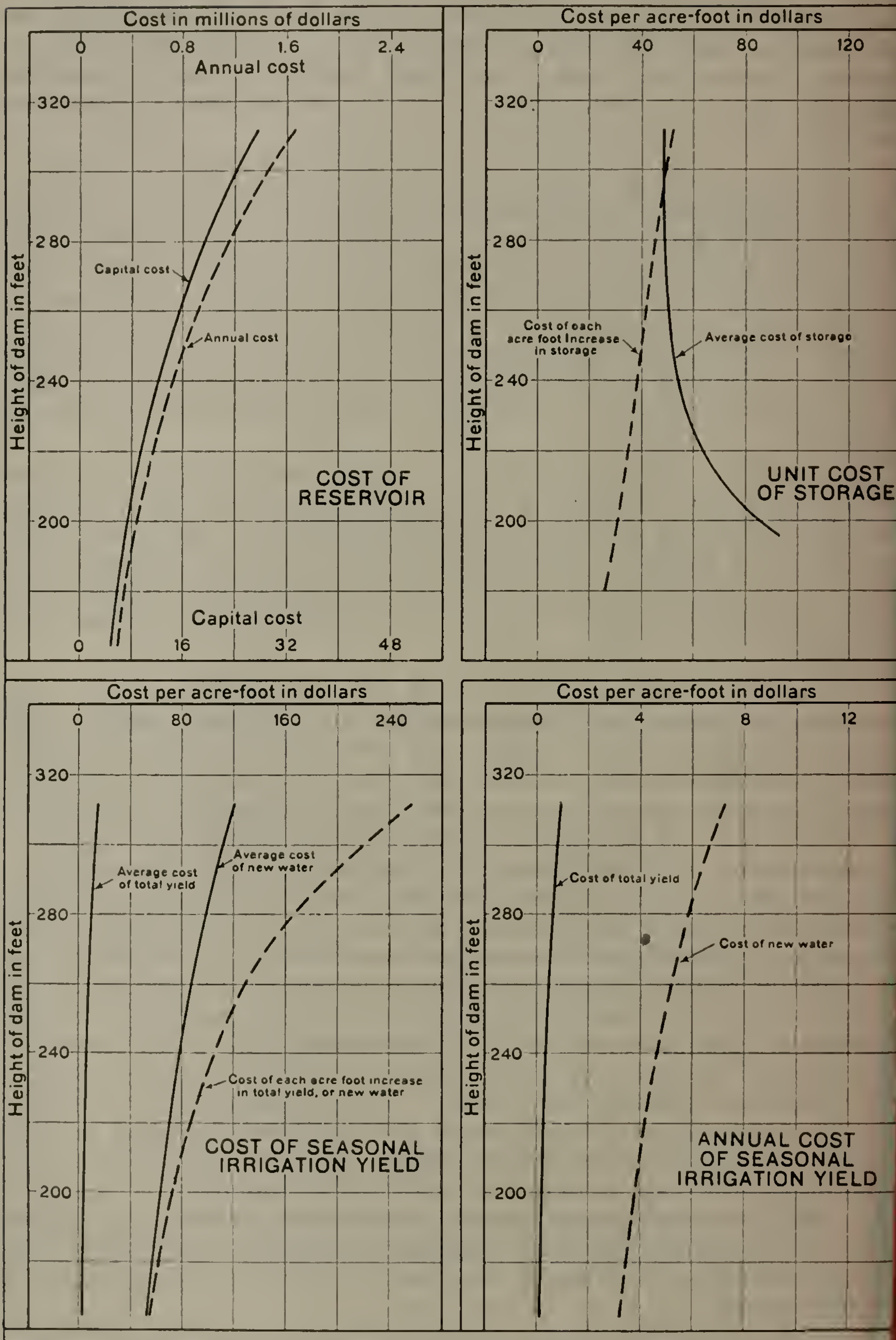
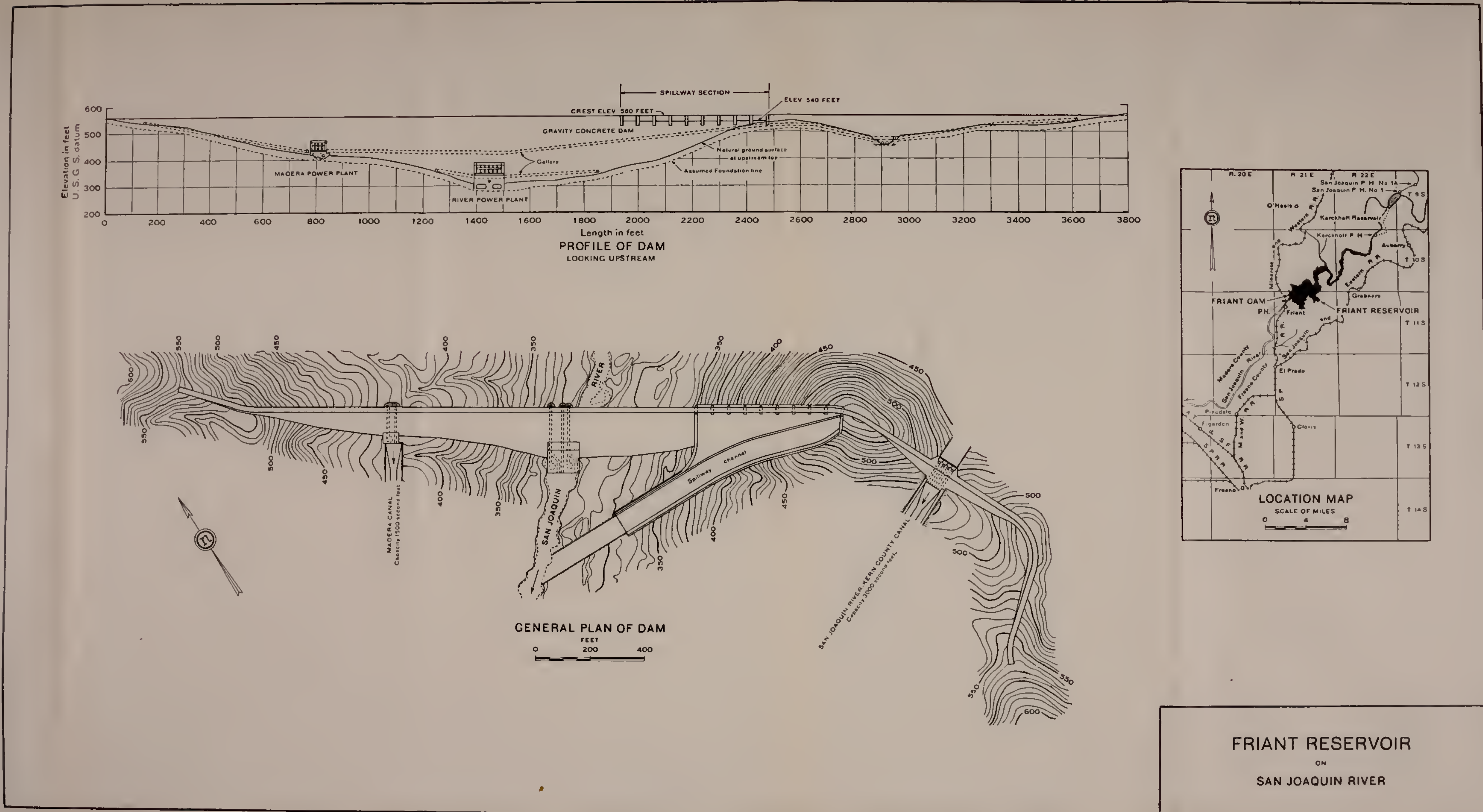


PLATE XLVII



COST OF RESERVOIR CAPACITY AND UNIT YIELD OF WATER FOR IRRIGATION FROM FRIANT RESERVOIR



FRIANT RESERVOIR
ON
SAN JOAQUIN RIVER

channel, with a maximum height above the stream bed of 252 feet and a crest length of 3800 feet. An overflow spillway is provided at the left abutment. The spillway controls consist of nine drum gates, 15 feet high by 50 feet long, having an estimated combined discharging capacity of 92,000 second-feet, or 2.8 times the once-in-25-year flood. A concrete lined spillway channel 900 feet long and an unlined cut 300 feet long would convey the discharge to the river about 400 feet below the downstream toe of the dam. Two sets of irrigation outlets are located on either side of the river. The outlets for the Madera Canal are on the north side at elevation 418 feet and have a discharging capacity of 1500 second-feet, with a maximum water surface elevation of 415 feet in the canal. The San Joaquin River-Kern County Canal outlets are located in a saddle on the south side at elevation 455 feet and have a discharging capacity of 3000 second-feet, with a maximum water surface elevation of 467 feet in the canal. Outlets also are provided near the stream bed to be utilized for the release of lower San Joaquin River "Crop Land" waters under conditions of immediate initial development.

For flood regulation, a reserve storage space of 75,000 acre-feet and a maximum draw-down of 20 feet would be required. The required regulatory flood control outlet capacity of 15,000 second-feet is provided by the utilization of power plant by-passes and irrigation water outlets, with a reservoir water surface at elevation 535 feet.

Power Plants—A power plant of 30,000 kilovolt amperes capacity is located at the lower toe of the dam for utilizing the lower San Joaquin River "Crop Land" waters (see Chapter VIII) which would be released under the immediate initial development for the lower San Joaquin Valley. This plant is to be abandoned upon completion of the San Joaquin River Pumping System, or at such time when all the San Joaquin River water would be diverted at high elevations for exportation to the upper San Joaquin Valley. Based on a 10-year amortization period, the economic capacity of this plant has been determined as 30,000 kilovolt amperes. A second power plant of 10,000 kilovolt amperes capacity is proposed under conditions of ultimate development for utilization of water released at elevation 415 feet for the Madera Canal.

Cost of Friant Reservoir—The capital and annual costs of Friant Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 91. The estimated revenue from sale of electric energy and the net annual cost not covered by power revenue also are given in the table for both the immediate initial and ultimate developments.

TABLE 91

COST OF FRIANT RESERVOIR

Height of dam, 252 feet. Gross capacity of reservoir, 400,000 acre-feet.
Net effective capacity of reservoir, 270,000 acre-feet.
Capacity of spillway, 92,000 second-feet.
Capacity of irrigation outlets, 7,500 second-feet.
Flood control outlet capacity, 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		50,000
Lands and improvements flooded and clearing		250,000
Excavation for dam, 350,000 cubic yards at $1.00 to $5.00	$1,000,000	
Mass concrete, 1,293,000 cubic yards at $6.30	8,146,000	
Reinforced concrete, 3,600 cubic yards at $17.00 to $30.00	68,000	
Spillway gates	170,000	
Spillway channel	360,000	
Irrigation outlet and sluiceways	164,000	
(Power outlets and controls included in cost of power plant)		
Drilling, grouting, drains and contraction seals	126,000	
		10,034,000
Miscellaneous		128,000
Subtotal		$10,472,000
Administration and engineering at 10 per cent		1,047,000
Contingencies at 15 per cent		1,571,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		910,000
Total capital cost of dam and reservoir		$14,000,000

Cost of Power Plants and Appurtenances for Friant Reservoir

Immediate Initial Development.—Power plant located at lower toe of dam for utilizing lower San Joaquin "crop land" waters, to be abandoned at such time as all San Joaquin River water shall be diverted for exportation at higher elevations. Selection of economic capacity based on a 10-year amortization period.

Capacity, 30,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total capital cost of power plant including outlets, penstocks and controls $1,500,000

Ultimate Development.—Power plant located at elevation 415 for utilizing water diverted through Madera Canal.

Capacity, 10,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total capital cost of power plant $500,00

Annual Cost of Friant Reservoir and Power Plants

Immediate Initial Development—	
Gross annual cost of dam and reservoir	$840,000
Gross annual cost of power plant	222,000
Total gross annual cost	$1,062,000
Average annual revenue from sale of electric energy, 105,000,000 kilowatt-hours at $0.0035	$367,000
Average net annual cost not covered by revenue from sale of electric energy	$695,000
Ultimate Development—	
Gross annual cost of dam and reservoir	$840,000
Gross annual cost of power plant	45,000
Total gross annual cost	$885,000
Average annual revenue from sale of electric energy, 23,000,000 kilowatt-hours at $0.0035	$80,000
Average net annual cost not covered by revenue from sale of electric energy	$805,000

Pine Flat Reservoir on Kings River.

In order to provide for the fullest practicable development and utilization of the run-off of Kings River for ultimate development, surface storage is desirable. It would increase the amount of water available for utilization, would improve the characteristics of supply and would provide a more flexible plan of development and operation than one without surface storage regulation. Accordingly, a surface storage unit is proposed on Kings River for ultimate development.

The dam site for the Pine Flat Reservoir on the Kings River is located in Section 2, Township 13 South, Range 24 East, M. D. B. and M., in Fresno County, about 26 miles easterly from the city of Fresno.

The Pine Flat site is the only one on Kings River strategically located and of adequate potential capacity to properly regulate the waters of the stream to meet the ultimate needs of the Kings River service area. There are several other sites on the South and Middle forks above Pine Flat which have been investigated by public and private agencies in connection with water supply and hydroelectric power projects. Some of these if developed would be useful in supplementing Pine Flat storage.

The drainage areas on the Kings River watershed, above the Pine Flat dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	386 square miles
Area between elevations 5000 and 10,000 feet	824 square miles
Area between elevations 2500 and 5000 feet	201 square miles
Area below elevation 2500 feet	133 square miles
Total area above Pine Flat dam site	1544 square miles

Present Developments on Kings River—The only existing development above the Pine Flat site is the Balch Power Plant of the San Joaquin Light and Power Corporation with an installed capacity of 33,000 kilovolt amperes. The present plant operates entirely on natural stream flow. Additional installation, dependent on storage development, is contemplated. Below Piedra are the diversions of an elaborate system of canals for the distribution of water to a gross area of some 900,000 acres of land on or below the Kings River Delta. A discussion of these diversions and water rights has been presented in Chapter IV. The total area irrigated in 1929 was approximately 600,000 acres.

Water Supply—The water supply available for regulation is the flow of Kings River, for which the estimated mean seasonal run-off for the 40-year period, 1889–1929, is 1,889,000 acre feet. Details of run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 1200 feet, was prepared from surveys made by the Kings River Water Conservation District in 1922. A map of the dam site, scale one inch equals 100 feet, was prepared from these surveys and supplemental surveys made by the State in 1925. Table 92 sets forth areas and capacities for various heights of dam.

The difference in total annual cost of water delivered on the land in the Kings River area, whether regulation of Kings River run-off be effected entirely by the utilization of ground water storage and pumping, or whether it be obtained by a combination of surface storage regulation and ground water storage and pumping, was shown by analysis to be very slight. However, after making trial studies of yield and cost for various capacity reservoirs, and after consideration of the limitations and possible accomplishments of a proposed plan of development and operation, including the value of existing rights and the operations thereunder, the methods of irrigation practiced in various parts of the Kings River area, the value of incidental power development, the value of storage space for flood control, and the desirability and necessity of surface storage regulation for ground water recharge and for furnishing an adequate surface supply for the nonabsorptive areas in Tulare Lake vicinity, it was concluded that

TABLE 92

AREAS AND CAPACITIES OF PINE FLAT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
48	600	125	2,000
68	620	325	6,000
88	640	550	15,000
108	660	850	28,000
128	680	1,225	49,000
148	700	1,525	77,000
168	720	1,875	110,000
188	740	2,200	152,000
208	760	2,475	198,000
228	780	2,850	251,000
248	800	3,225	312,000
268	820	3,575	380,000
274	826	3,680	400,000
288	840	3,925	455,000
308	860	4,375	537,000
328	880	4,745	630,000
348	900	5,450	732,000

Pine Flat Reservoir should be included as a unit for ultimate development of the State Water Plan for the San Joaquin River Basin and that its economic and practicable capacity for this purpose would be 400,000 acre-feet.

The reservoir site is situated in the lower mountain area, about six miles above the edge of the valley floor, below all intereference with present or future power development and at a point where practically the entire Kings River run-off can be regulated. With the capacity selected, the reservoir would have a flow line elevation of 826 feet, a length of 14 miles, a maximum width of one and one-half miles and a surface area of 3680 acres. Most of the flooded area is steep, rocky, mountain land, covered with brush and small timber. In Pine Flat about 80 acres are planted to orchard and vineyard. Other improvements consist of a few scattered ranch houses. The main Kings River Canyon road would be submerged and would require about twelve miles of relocation together with a telephone line of light construction.

In making yield studies, a net seasonal reservoir evaporation loss of four feet depth on the reservoir surface was used. The mean seasonal irrigation yield from this reservoir, operated in conjunction with ground water storage in the Kings River Delta, for the 40-year period, 1889–1929, would have been 1,764,000 acre feet. Details of reservoir yields and utilization are given in Chapter VII.

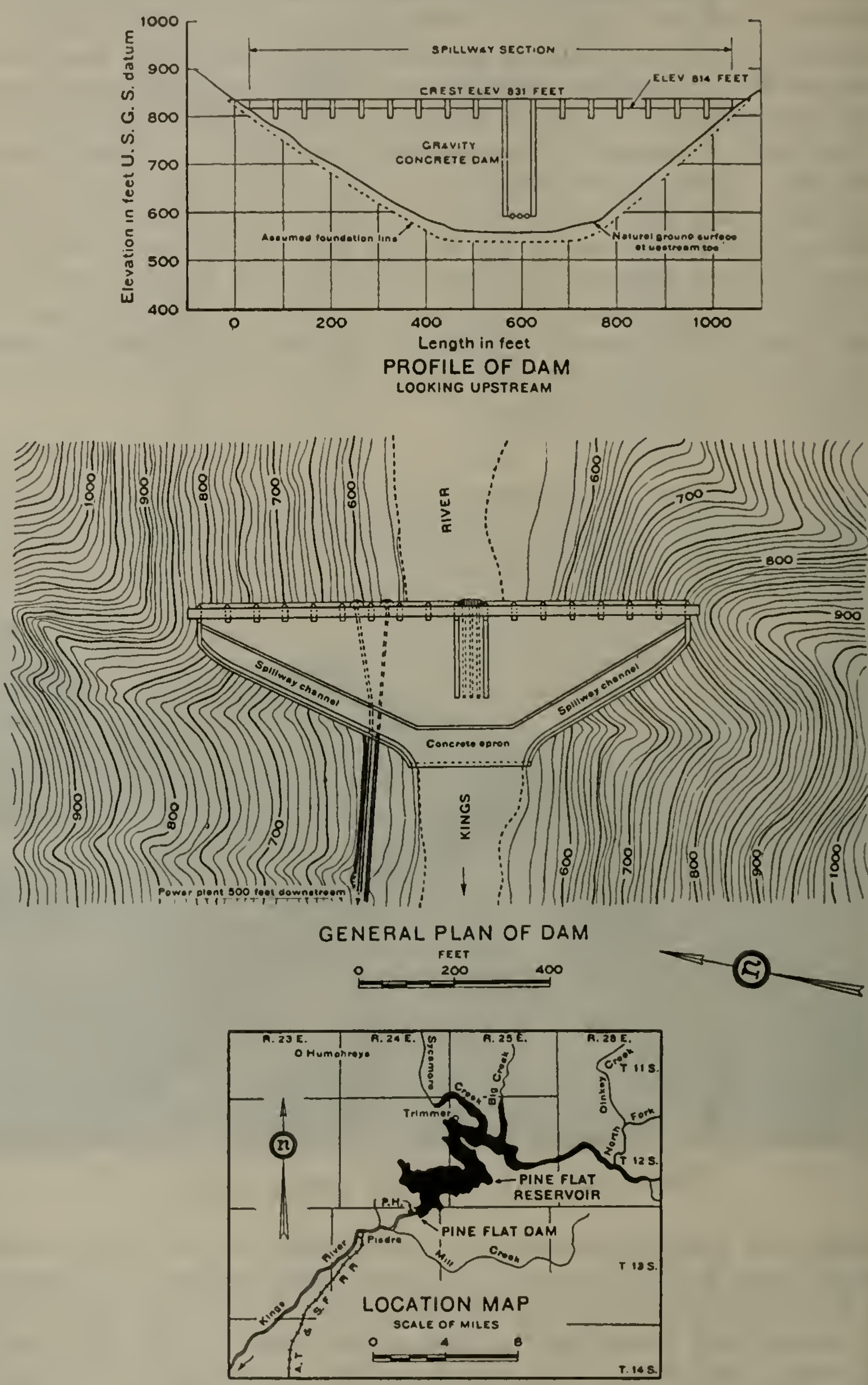
Dam Site—Several dam sites have been investigated by different interests in the section of the canyon between Pine Flat and Piedra. Surveys, exploration and examination of the adopted site were made by the Kings River Water Conservation District. After making a geological examination (see Appendix C) and additional topographic surveys, this same site was chosen. The geological examination shows that the character of the rock and the topographic development at this site are well suited to the construction of a concrete dam. The rock mass is a ''greenstone,'' the chief rock making member of which is horneblende. Several systems of joints break the rock mass into relatively small blocks, but without displacement of the joint blocks or parting of the joint walls. Although being a universal structural defect of the rock mass, this system of joints is not to be considered as greatly reducing the strength of the whole rock mass or the safety of a structure founded upon it. Examination of the cores shows the joints to be closed and tight at a shallow depth below the rock line in the stream bed to the extent that they would probably refuse grout. On the abutments, the rock is covered with a shallow overburden of clay soil and is partially disintegrated to depths of from three to fifteen feet. Spotted over the site are some joints below these depths where water has circulated. It is estimated that, on the average, stripping of 20 to 30 feet in the stream bed and 10 to 12 feet on the abutments would remove all loose material and reveal sound rock. Some portions would require but five to eight feet of stripping, while limited areas would require as much as 30 feet. The general geology and the location of diamond drill holes at this site are shown on plates in Appendix C of this report.

PLATE XLIX

PINE FLAT DAM SITE ON KINGS RIVER

Dam and Appurtenances—The topography of the dam site and general layout of the proposed dam and appurtenances are shown on Plate L, "Pine Flat Reservoir on Kings River." The height of dam above stream bed, including five feet of freeboard, is 274 feet and the crest length, 1080 feet. The dam is a concrete gravity-type structure, straight in plan, with an overflow spillway occupying all of the crest except 70 feet in the center and 30 feet at each abutment. The spillway is controlled by 16 drum gates 12 feet high by 50 feet long and has an estimated discharging capacity of 120,000 second-feet or 3.5 times the once-in-25-year flood. A bucket section and concrete lined spillway channels along the downstream toe of the dam are provided to convey the discharge to a concrete apron in the river channel.

PLATE I



PINE FLAT RESERVOIR

ON

KINGS RIVER

Reserve space of 80,000 acre-feet with a maximum drawdown of 25 feet would be required for the regulation of winter floods to a maximum flow of 15,000 second-feet, exceeded once in 100 years on the average. The required outlet capacity of 15,000 second-feet is provided through the irrigation outlets and power plant by-passes.

Three 78-inch diameter pipes through the dam, at elevation 590 feet, are provided for the release of irrigation water. These have a combined discharging capacity of 3000 second-feet under a minimum head of 30 feet and are controlled by needle valves and emergency slide gates. Additional irrigation water would be released through the power plant turbines and by-passes.

Power Plant—Considering the average value of power at $0.002 per kilowatt hour with no power reserve storage and assuming releases in accordance with irrigation use only, the economic capacity of the power installation for Pine Flat Reservoir is estimated to be 40,000 kilovolt amperes. The power plant would be located on the right side of the river about 1000 feet below the downstream toe of the dam, the turbines being supplied through steel penstocks. The cost of the complete power development is estimated at $50 per kilovolt ampere.

Cost of Pine Flat Reservoir—The capital and annual costs of Pine Flat Reservoir estimated in accord with bases previously presented in this chapter, are set forth in Table 93. The estimated revenue from the sale of electric energy and the net annual cost not covered by power revenue also are given in the table.

TABLE 93

COST OF PINE FLAT RESERVOIR

Height of dam, 274 feet. Capacity of reservoir, 400,000 acre-feet.
Capacity of spillway, 120,000 second-feet.
Capacity of irrigation outlets, 3,000 second-feet.
Flood control outlet capacity of 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		75,000
Lands and improvements flooded and clearing		500,000
Excavation for dam, 168,000 cubic yards at $3.50 to $5.00	$702,000	
Mass concrete, 727,000 cubic yards at $6.50	4,726,000	
Reinforced concrete, 5,500 cubic yards at $18.00 to $30.00	106,000	
Spillway gates	234,000	
Spillway channel	400,000	
Irrigation outlets and sluiceways	167,000	
(Power plant outlets and controls included in cost of power plant)		
Drilling, grouting, drains and contraction seals	64,000	
		6,399,000
Miscellaneous		196,000
Subtotal		$7,180,000
Administration and engineering at 10 per cent		718,000
Contingencies at 15 per cent		1,077,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		625,000
Total capital cost of dam and reservoir		$9,600,000

Cost of Power Plant for Pine Flat Reservoir

Capacity, 40,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total capital cost of power plant, including outlets, penstocks and controls	$2,000,000

Annual Cost of Pine Flat Reservoir and Power Plant

Gross annual cost of dam and reservoir	$574,000
Gross annual cost of power plant	168,000
Total gross annual cost	$742,000
Average annual revenue from sale of electric energy, 100,500,000 kilowatt hours at $0.002	$201,000
Average net annual cost not covered by revenue from sale of electric energy	$541,000

Ward Reservoir Site on Kaweah River.

The dam site for the Ward Reservoir site on the Kaweah River is located in Section 33, Township 17 South, Range 28 East, M. D. B. and M., in Tulare County about 20 miles east of the city of Visalia. This is the only reservoir site on the main stream offering possibilities of full regulation of the Kaweah River. No sites of sufficient size to be important have been found on the main branches of the stream.

The drainage areas on the Kaweah River watershed, above the Ward dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	37 square miles
Area between elevations 5000 and 10,000 feet	275 square miles
Area between elevations 2500 and 5000 feet	141 square miles
Area below elevation 2500 feet	61 square miles
Total area above Ward dam site	514 square miles

Present Developments on Kaweah River—The only existing developments above the Ward site consist of three power plants of the Southern California Edison Company, Kaweah No. 1, No. 2 and No. 3, having installed capacities of 2500, 3500 and 3500 kilovolt amperes, respectively. The supply for Kaweah No. 1 is diverted from East Fork. Kaweah No. 3 diverts near the junction of the Marble Fork and Middle Fork. Diversion for Kaweah No. 2 is made from the Middle Fork immediately below Kaweah No. 3 tailrace. The diversion systems, water rights and irrigated areas on the Kaweah Delta have been discussed in Chapter IV.

Water Supply—The water supply available at this site is the full natural run-off of the Kaweah River of which the seasonal mean for the 40-year period, 1889–1929, is estimated as 443,000 acre-feet. The mean seasonal yield for this period, utilizable without surface storage, is estimated as 435,000 acre-feet. Details of run-off and utilization by ground water storage have been presented in Chapters II and IV, respectively.

Reservoir Site and Capacity—A contour map of the reservoir site, scale one inch equals 400 feet, was prepared by George B. Sturgeon from a survey made in 1917. The State made a survey and prepared a contour map of the dam site, scale one inch equals 100 feet, in 1930. Table 94 sets forth areas and capacities for various heights of dam.

TABLE 94

AREAS AND CAPACITIES OF WARD RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
45	660	101	1,800
65	680	173	4,500
85	700	253	8,800
105	720	384	15,200
125	740	518	24,000
145	760	691	36,300
165	780	901	51,900
185	800	1,111	72,000
205	820	1,291	96,000
225	840	1,527	124,000
245	860	1,778	156,800
265	880	2,031	195,500
285	900	2,296	238,600
305	920	2,582	287,400
325	940	2,725	341,800

Economics of Surface Storage on Kaweah River—The construction of the Ward Reservoir is not included in the State Plan. The wide "U" shaped channel at this dam site makes the unit cost of surface storage relatively expensive. The present high degree of conservation of stream flow in the Kaweah Delta area is secured by the utilization of ground water storage and pumping in a large absorptive area. The net irrigable area of about 35,000 acres, some of which is nonabsorptive, situated above the proposed location of the San Joaquin River-Kern County Canal in the Kaweah Basin, could be furnished an ample surface supply every season by direct diversion from the Kaweah River without surface storage development. Cost estimates and yield studies were made of a reservoir at the Ward site for various storage

PLATE LI

WARD DAM SITE ON KAWEAH RIVER

capacities. Analyses of the economics of stream flow utilization with reservoirs of various capacities at this site, operated in conjunction with ground water storage and pumping, showed that no increase in utilizable yield could be obtained thereby and that the unit cost of water delivered to the land would considerably exceed that obtainable from a supply developed without surface storage.

Dam Site—The dam site is located about three miles below the town of Three Rivers and lies wholly within an area composed of granitic rock. The stream has cut a wide "U" shaped channel through this formation. A geological examination (see Appendix C) shows that the granite mass has developed a complex series of irregular joint planes. The effect of weathering along joint planes makes it uncertain without subsurface exploration as to the extent of stripping and pressure grouting necessary. For the purposes of preliminary estimating it was considered that the stripping would be uneven, and an average allowance was made for 25 feet of excavation perpendicular to the slope, over the entire site.

Pleasant Valley Reservoir on Tule River.

The dam site for the Pleasant Valley Reservoir on the Tule River is located in Sections 17 and 18, Township 21 South, Range 29 East, M. D. B. and M., in Tulare County, about nine miles east of the city of Porterville. The South Fork joins the main river about three miles below the Pleasant Valley dam site. A reservoir site was investigated on that fork, just below the Tule River Indian Reservation, but sufficient capacity could not be obtained to control the run-off. On the Middle Fork there is a small reservoir site below the mouth of Bear Creek. The Pleasant Valley site on the main stream is the only one capable of being developed to the capacity required for a high degree of utilization of the run-off of most of the watershed.

The drainage areas on the Tule River watershed, above the Pleasant Valley dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	98 square miles
Area between elevations 2500 and 5000 feet	73 square miles
Area below elevation 2500 feet	93 square miles
Total area above Pleasant Valley dam site	264 square miles

The South Fork has a drainage area of 74 square miles above the gaging station on the Tule River Indian Reservation.

Present Developments on Tule River—The only existing developments above the Pleasant Valley site are two power plants on Middle Fork. The upper plant, owned by the San Joaquin Light and Power Corporation, has an installed capacity of 6000 kilovolt amperes. It is located at the junction of the north and south forks of Middle Fork and diverts its water supply from the former. The lower plant, owned by Southern California Edison Company, has an installed capacity of 2500 kilovolt amperes. It is located on Middle Fork above its junction with North Fork and diverts its supply immediately below the tailrace of the upper plant. Existing conditions of irrigation development on the Tule River Delta have been discussed in Chapter IV.

Water Supply—The estimated mean seasonal run-off above the Pleasant Valley dam site for the 40-year period, 1889–1929, is 99,700 acre-feet. The South Fork, with a mean seasonal run-off for the 40-year period of 30,300 acre-feet, could not be regulated by storage, but the run-off therefrom would be pooled with reservoir releases on the main river, so regulated as to result in a high degree of utilization of the entire Tule River run-off. Details in regard to run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir and dam site, scale one inch equals 500 feet, was prepared from a survey made by the State in 1921. Table 95 sets forth areas and capacities for various heights of dam.

A study of the economics of utilization of the run-off of Tule River, including South Fork, with surface storage regulation on the main Tule River operated in conjunction with ground water storage, shows that a surface reservoir capacity of 39,000 acre-feet would be required and justified. At this capacity the flow line elevation of Pleasant Valley Reservoir would be 775 feet and the submerged area

TABLE 95

AREAS AND CAPACITIES OF PLEASANT VALLEY RESERVOIR

Height of dam, in feet (10-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
50	700	96	1,500
60	710	168	2,800
70	720	239	4,900
80	730	319	7,700
90	740	415	11,300
100	750	612	16,500
110	760	845	23,700
120	770	1,093	33,400
125	775	1,270	39,000
130	780	1,451	46,200
140	790	1,849	62,700
150	800	2,198	82,900

1270 acres. This reservoir area is chiefly uncultivated grazing land. Several citrus groves fringe the valley but are situated above the flow line. About three miles of the Porterville-Springville Highway would require relocation and about 3.5 miles of the Springville branch of the Southern Pacific Railroad would be submerged, involving relocation or compensation for abandonment.

In making the irrigation yield studies on the Tule River, a net seasonal reservoir evaporation loss of four feet in depth on the reservoir surface was used. With the regulated flow allocated to high rim lands in the form of a gravity supply and unregulated flows used for the irrigation of lower lands and the replenishment of ground water storage, the mean seasonal utilizable yield for the 40-year period, 1889–1929, including that from the South Fork, would have been 128,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

PLATE LII

PLEASANT VALLEY DAM SITE ON TULE RIVER

Dam Site—A geological examination (see Appendix C) of the Pleasant Valley dam site shows the bedrock to be of granitic formation varying in texture and mineral constituents within comparatively small areas. Weathering has attacked the rock, producing gentle slopes at the dam site abutments. The rock outcrops are principally dislodged joint blocks with but little rock found in place. The topographic and geological characteristics of the site dictate the adoption of an earth-fill dam as most suitable and designs and estimates have been based on this type of dam. No subsurface exploration has been made. As the deep weathering of the bedrock has produced gentle slopes and no outcrops show near the stream bed, it is estimated that excavation to a depth of 50 feet would be required for the cutoff wall at the upstream toe of the main dam, and from 50 to 60 feet for the auxiliary dam required in a saddle northwest of the main dam site.

Dam and Appurtenances—The topography of the dam site and the general layout of the proposed dam and appurtenances are shown on Plate LIII, "Pleasant Valley Reservoir on Tule River." The maximum height of the main dam is 125 feet, and that of the auxiliary dam 45 feet, including 10 feet of freeboard. The main dam has a crest length of 1660 feet, an upstream slope of 3 to 1 and a downstream slope of 2½ to 1. The auxiliary dam has the same slopes as the main dam and a crest length of 1150 feet.

The spillway, of the overflow wing type, is located at the left abutment of the auxiliary dam. It discharges into a lined channel extending about 500 feet downstream from the crest of the dam. It has an estimated capacity of 20,000 second-feet or 3.2 times the once-in-25-year flood.

The irrigation outlet consists of a reinforced concrete gate tower equipped with three, five feet by five feet inlet gates of the caterpillar type, connecting with a 70-inch diameter reinforced concrete conduit 670 feet long extending under the dam. The discharging capacity with a minimum head of eight feet is estimated at 260 second-feet. No hydroelectric power development is proposed at this site.

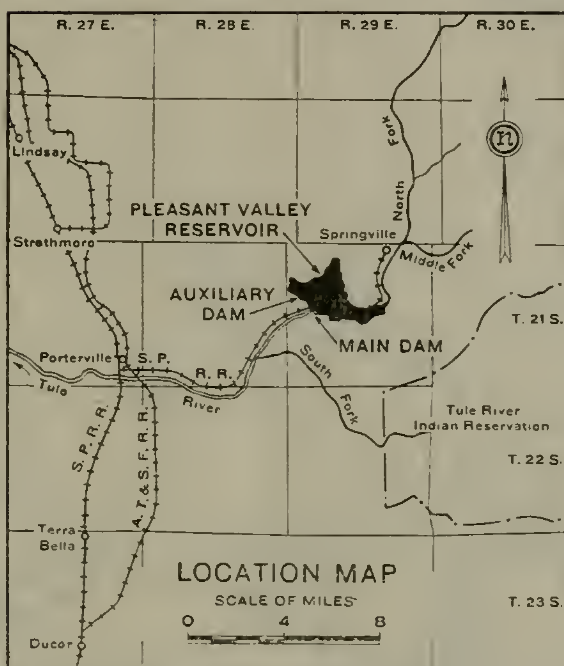
Cost of Pleasant Valley Reservoir—The capital and annual costs of Pleasant Valley Reservoir, estimated in accord with bases previously presented in this chapter, are set forth in Table 96.

TABLE 96

COST OF PLEASANT VALLEY RESERVOIR

Height of dam, 125 feet. Capacity of reservoir, 39,000 acre-feet.
Capacity of spillway, 20,000 second-feet.
Capacity of irrigation outlet, 260 second-feet.

Exploration		$12
Diversion of river during construction		60
Lands and improvements flooded and clearing		325
Excavation for dam, 75,000 cubic yards at $0.75 to $3.00	$90,000	
Earth fill in dam, 1,290,000 cubic yards at $0.75	968,000	
Reinforced concrete face, 9,200 cubic yards at $15.00	138,000	
Miscellaneous reinforced concrete and cut-off walls, 12,000 cubic yards at $15.00 to $18.00	195,000	
Spillway overflow weir	90,000	
Spillway channel	160,000	
Irrigation outlet tower, conduit and gates	55,000	
		1,69
Miscellaneous		7
Subtotal, dam and reservoir		$2,16
Administration and engineering at 10 per cent		21
Contingencies at 15 per cent		32
Interest during construction, based on an interest rate of 4.5 per cent per annum		18
Total capital cost of dam and reservoir		$2,90
Total annual cost of dam and reservoir		$17



PLEASANT VALLEY RESERVOIR

ON

TULE RIVER

joint blocks with but little rock found in place. The topographic and geological characteristics of the site dictate the adoption of an earth-fill dam as most suitable and designs and estimates have been based on this type of dam. No subsurface exploration has been made. As the deep weathering of the bedrock has produced gentle slopes and no outcrops show near the stream bed, it is estimated that excavation to a depth of 50 feet would be required for the cutoff wall at the upstream toe of the main dam, and from 50 to 60 feet for the auxiliary dam required in a saddle northwest of the main dam site.

Dam and Appurtenances—The topography of the dam site and the general layout of the proposed dam and appurtenances are shown on Plate LIII, "Pleasant Valley Reservoir on Tule River." The maximum height of the main dam is 125 feet, and that of the auxiliary dam, 45 feet, including 10 feet of freeboard. The main dam has a crest length of 1660 feet, an upstream slope of 3 to 1 and a downstream slope of 2½ to 1. The auxiliary dam has the same slopes as the main dam and a crest length of 1150 feet.

The spillway, of the overflow wing type, is located at the left abutment of the auxiliary dam. It discharges into a lined channel extending about 500 feet downstream from the crest of the dam. It has an estimated capacity of 20,000 second-feet or 3.2 times the once-in-25-year flood.

The irrigation outlet consists of a reinforced concrete gate tower, equipped with three, five feet by five feet inlet gates of the caterpillar type, connecting with a 70-inch diameter reinforced concrete conduit 670 feet long extending under the dam. The discharging capacity with a minimum head of eight feet is estimated at 260 second-feet. No hydroelectric power development is proposed at this site.

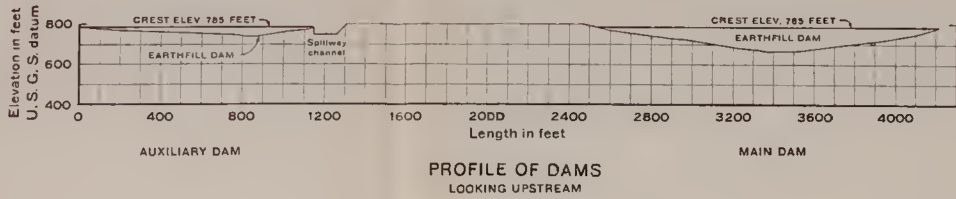
Cost of Pleasant Valley Reservoir—The capital and annual costs of Pleasant Valley Reservoir, estimated in accord with bases previously presented in this chapter, are set forth in Table 96.

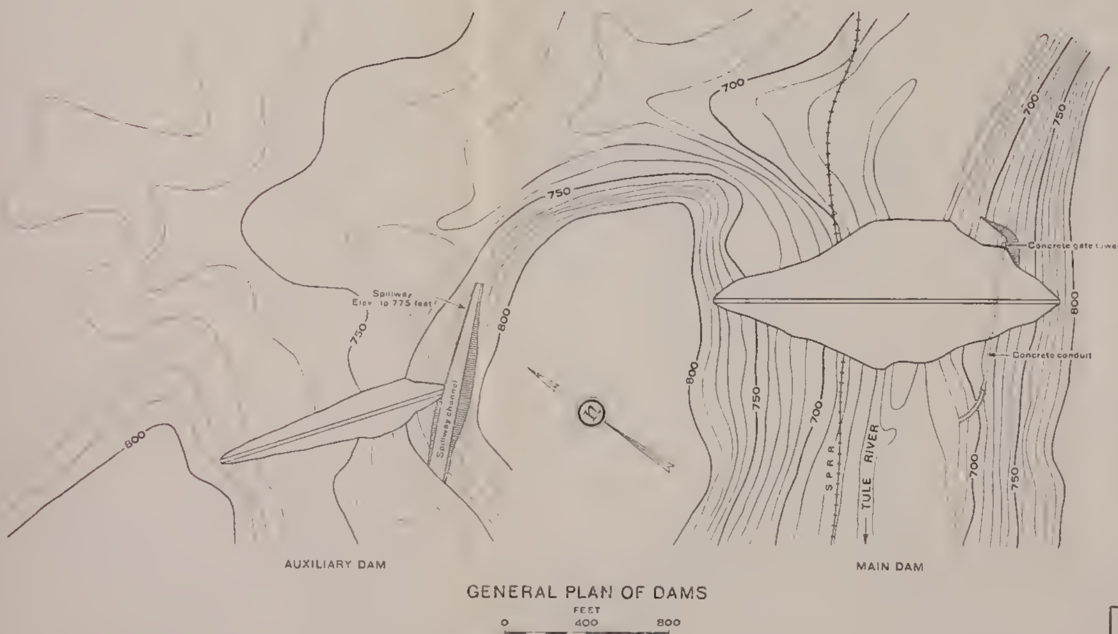
TABLE 96

COST OF PLEASANT VALLEY RESERVOIR

Height of dam, 125 feet. Capacity of reservoir, 39,000 acre-feet.
Capacity of spillway, 20,000 second-feet.
Capacity of irrigation outlet, 260 second-feet.

Exploration		$12,000
Diversion of river during construction		60,000
Lands and improvements flooded and clearing		325,000
Excavation for dam, 75,000 cubic yards at $0.75 to $3.00	$90,000	
Earth fill in dam, 1,290,000 cubic yards at $0.75	968,000	
Reinforced concrete face, 9,200 cubic yards at $15.00	138,000	
Miscellaneous reinforced concrete and cut-off walls, 12,000 cubic yards at $15.00 to $18.00	195,000	
Spillway overflow weir	90,000	
Spillway channel	160,000	
Irrigation outlet tower, conduit and gates	55,000	
		1,696,000
Miscellaneous		76,000
Subtotal, dam and reservoir		$2,169,000
Administration and engineering at 10 per cent		217,000
Contingencies at 15 per cent		325,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		189,000
Total capital cost of dam and reservoir		$2,900,000
Total annual cost of dam and reservoir		$171,000





PLEASANT VALLEY RESERVOIR

ON

TULE RIVER

Isabel

locat
forks
M., i
Bake
of H
tions

one a
to th
these
The
junc
belo
and

Town
Rang
No.
to th
pied
has
A r
inter
dam
acre
irrig

Tow
nort
inve
Ker
rati
this
acre
(see
coul
of p
As
the
the
it is

qua
suff
by

Isa

Are
Are
Are
Are

Isabella Reservoir on Kern River.

The main dam site for the Isabella Reservoir on the Kern River is located about three miles below the confluence of North and South forks in Section 36, Township 26 South, Range 32 East, M. D. B. and M., in Kern County, about 35 miles northeasterly from the city of Bakersfield. An auxiliary dam also would be required at the crest of Hot Springs Valley 1.5 miles south of the town of Isabella in Sections 29 and 30, Township 26 South, Range 33 East.

There are two favorable reservoir sites located on the South Fork—one at Monache Meadows and the other at Rock House Meadows. Due to the relatively smaller run-off of the South Fork, the utilization of these sites would regulate only a small part of Kern River run-off. The North Fork offers no opportunity for adequate storage above the junction with the South Fork. Two other sites have been investigated below Isabella on the main Kern River. These comprise Bakersfield and Borel sites.

The dam site for the Borel Reservoir is located in Section 32, Township 27 South, Range 31 East, and Section 5, Township 28 South, Range 31 East, M. D. B. and M., above the intake of the existing Kern No. 1 Power Plant. The reservoir would extend 13 miles upstream to the tailrace of the existing Borel Power Plant. Although unoccupied at the present time, the Southern California Edison Company has considered the development of this section of the river for power. A reservoir constructed to the maximum capacity that would not interfere with the operation of the Borel Power Plant would require a dam 415 feet high, flood an area of 1830 acres and impound 238,000 acre feet of water. This capacity is considered inadequate for proper irrigation regulation of Kern River run-off.

The dam site for the Bakersfield Reservoir is located in Section 35, Township 28 South, Range 28 East, M. D. B. and M., about six miles northeast of Bakersfield. A dam 226 feet in height, the highest one investigated at this site, would back water up to the tailrace of the Kern Canyon Power Plant of the San Joaquin Light and Power Corporation, the elevation of which is 685 feet. A reservoir constructed to this elevation would flood an area of 5560 acres and impound 569,000 acre-feet of water. A geological examination in the region of this site (see Appendix C) showed that suitable foundations for a concrete dam could not be obtained. However, it is thought that an earth-fill dam of proper dimensions could be built that would be stable and safe. As the elevation of this reservoir is below the diversion elevation of the Kern River Canal required in the Ultimate State Water Plan for the delivery of Kern River water to the rim lands south of Kern River, it is not suitable for inclusion in the proposed plan of development.

The Isabella site is the only one having a potential capacity adequate for proper regulation of Kern River run-off and located at a sufficiently high elevation to permit the regulated supply to be diverted by gravity to the valley floor rim lands south of Kern River.

The drainage areas on the Kern River watershed, above the Isabella dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	266 square miles
Area between elevations 5000 and 10,000 feet	1392 square miles
Area between elevations 2500 and 5000 feet	421 square miles
Area below elevation 2500 feet	1 square mile
Total area above Isabella dam site	2080 square miles

PLATE LIV

Site of Main Isabella Dam

Site of Auxiliary Dam Across Hot Spring Valley

ISABELLA DAM SITE ON KERN RIVER

PLATE LV

BOREL DAM SITE ON KERN RIVER

Present Developments on Kern River—The present developments of importance on Kern River above the valley floor are the power plants of the Southern California Edison Company and the San Joaquin Light and Power Corporation. The former company has three plants which develop most of the head from elevation 3600 feet down to elevation 950 feet. Kern No. 3, with an installed capacity of 35,000 kilovolt amperes, located above Kernville, is the newest and largest of the system. The Borel Plant with an installed capacity of 10,000 kilovolt amperes, located at the upper end of the canyon below Kernville, is the oldest and smallest of the system. Kern No. 1 with an installed capacity of 20,000 kilovolt amperes utilizes most of the steep drop at the lower end of the canyon. Immediately below Kern No. 1 is the Kern Canyon Plant of the San Joaquin Light and Power Corporation which utilizes the remaining head above the mouth of the canyon. It has an installed capacity of 10,600 kilovolt amperes. All of the foregoing plants, except Kern No. 1, utilize up to about 600 second-feet of flow. The conveyance capacity of Kern No. 1 development is limited to about 390 second-feet. Irrigation development and diversions on the valley floor have been discussed in Chapter IV.

Water Supply—The water supply available for regulation in Isabella Reservoir is the impaired run-off of Kern River as measured at the gaging station (First Point of Measurement) about five miles northeast of Bakersfield. The run-off originating between that station and the Isabella dam site is relatively small. The mean seasonal ultimate net run-off for the 40-year period, 1889–1929, is estimated as 714,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 2000 feet, was made under the supervision of Ralph Bennett in 1916 to the 2700-foot contour. In 1920 a topographic survey of the reservoir site below elevation 2600 feet, scale one inch equals 400 feet, was made by the State. The Kern River Water Storage District made a survey and prepared a contour map of the dam site, scale one inch equals 50 feet, in 1925. Table 97 sets forth areas and capacities for various heights of dam.

TABLE 97

AREAS AND CAPACITIES OF ISABELLA RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
70	2,460	80	2,000
90	2,480	225	5,000
110	2,500	700	13,000
130	2,520	1,800	37,000
150	2,540	3,750	93,000
170	2,560	6,250	188,000
190	2,580	8,575	338,000
210	2,600	11,050	533,000
230	2,620	14,340	792,000
250	2,640	16,300	1,098,000

A study of the utilization of the Kern River run-off under conditions of ultimate development, through the combined means of surface and undergound storage, shows that a storage capacity of 338,000 acre-feet in Isabella Reservoir would provide most economically for the required surface storage regulation. For this capacity with a flow line at elevation 2580 feet, the reservoir would flood an area of 8575 acres, extending four miles up the North Fork and six miles up the South Fork from the dam site. The reservoir site is clear of timber and brush with the exception of willows and cottonwood trees along the stream channels, and the wooded growth in the three miles of river canyon between the dam site and the junction of the two forks. The lands in the North Fork Valley are not farmed as they were purchased years ago by the Kern River Development Company for the acquisition of diversion rights on that stream. Some 3750 acres of land in South Fork Valley, under the proposed flow line, are irrigated and cropped to corn and alfalfa or used for winter pasture. The improvements which would be submerged include the small settlements of Isabella and Kernville. The relocation and reconstruction of about ten miles of the Kern Canyon-Walker Pass State Highway along the south side of South Fork Valley and about ten miles of county road from Erskine Creek to a point one mile above Kernville with a river crossing at each end would be required. About ten miles of power transmission line and ten miles of telephone line also would require relocation.

Chief of the improvements to be submerged are the intake works and upper four miles of the Borel Canal. This canal, with a diversion right of 600 second-feet from the North Fork only, serves the Borel Power Plant of the Southern California Edison Company. It diverts at Kernville into an unlined channel leading to a settling basin formerly about one-half mile in length but now considerably restricted due to silt accumulation. The water surface elevation in this basin at the inlet to the canal proper is 2556 feet, U. S. G. S. datum. Four miles below this point the canal crosses the saddle of Hot Springs Valley with a flow line at elevation 2549. At this point an earth dam 55 feet in height would be required as an auxiliary to the concrete dam on Kern River, to develop the proposed storage. The treatment proposed for the interference with this established right on the stream is to provide an outlet to the Borel Canal at the site of the earth dam and, at all times when the reservoir surface would be above elevation 2549, to deliver the full capacity of 600 second-feet to that conduit. At times when the reservoir surface would be below elevation 2549, the Borel Plant would be out of service. The average seasonal loss in power output due to this method of operation has been calculated and its value at $0.004 per kilowatt hour capitalized at 10 per cent to estimate the cost of this interference. No additional hydroelectric power installation is proposed in the development of the Isabella site.

The net seasonal reservoir evaporation loss used in making yield studies at the Isabella site was three feet in depth on the reservoir surface. The mean seasonal yield for the 40-year period, 1889–1929, which could have been obtained for irrigation utilization from the operation of this reservoir in conjunction with ground water storage, is 670,000 acre-feet or 94 per cent of the mean seasonal impaired run-off for that period.

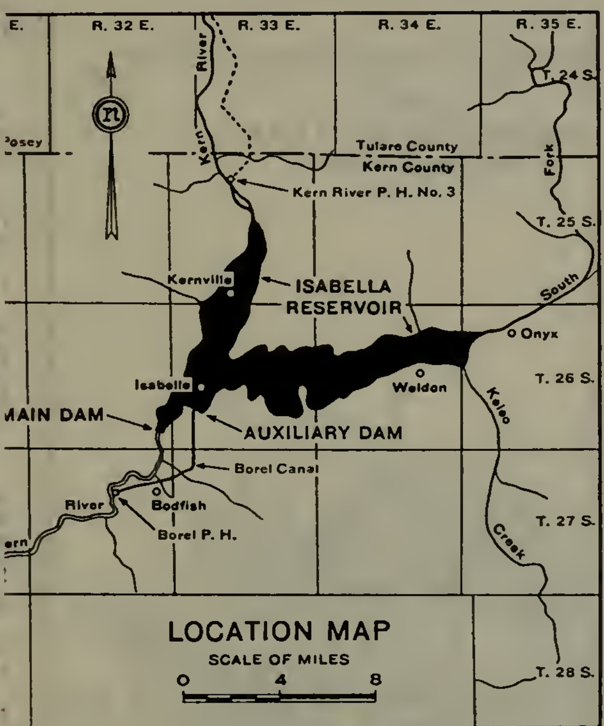
Dam Sites—A geological examination of the main dam site (see Appendix C) shows the bedrock to be a close textured granodiorite, with some large joint blocks displaced from the mass, but with joint walls of clean, unweathered sound rock. It is probable that few, if any, joints that might cause leakage or uplift under the dam would be found open upon uncovering streambed rock. Displaced joint blocks on the abutments would necessarily be removed in stripping the site. Some joints may be found open without appreciable displacement of the joint blocks, but the mass could be rendered sound by grouting. The upper abutments carry some disintegrated joint blocks and a light soil cover. On the average 20 feet of stripping should provide sound rock foundation. The site is well suited to a concrete structure.

The storage requirement necessitates an auxiliary dam in Hot Springs Valley. The log of a water well drilled on property a few hundred feet from the proposed auxiliary dam site at the saddle crest of this valley shows water-bearing sand to 110 feet and blue clay to 255 feet. The geologic history of the valley filling would lead to the conclusion that bedrock would not be found within reach of a cut-off wall, except possibly near the town of Isabella which lies at the easterly mouth of this valley at an elevation 25 feet below the valley crest. At Isabella, the rock would lie within the shear zone of a rift passing through Hot Springs Valley from Kernville to Bodfish and would probably contain open fractures which would pass water more freely than alluvium. Considering that the maximum height of an earth dam at the valley crest would be only 55 feet and that some leakage loss would be allowable, the proposed auxiliary dam site was concluded to be more desirable than the site considered near Isabella.

Dams and Appurtenances—The topography of the sites and the general layouts of the proposed dams and appurtenances are shown on Plate LVI, "Isabella Reservoir on Kern River." The main dam has a crest length of 780 feet and a maximum height of 190 feet above stream bed, including five feet of freeboard. It is a concrete gravity type structure, somewhat curved in plan to fit the topography. It has an overflow spillway at the right abutment, having an estimated discharging capacity of 57,000 second-feet or 3.4 times the once-in-25-year flood. The spillway discharge would be controlled by four drum gates 20 feet high by 45 feet long. A lined spillway channel is provided to convey the water to the river channel below the dam.

Reserve space of 67,000 acre-feet, involving a maximum drawdown of nine feet, would be provided for regulation of winter floods to a maximum flow of 7500 second-feet, exceeded once in 100 years on the average. The required capacity for flood regulation is provided by the irrigation outlets. These outlets consist of two 98-inch pipes through the dam, with a combined discharging capacity of 3500 second-feet under a minimum head of 25 feet and 8500 second-feet under a head of 170 feet. The outlets are controlled by needle valves and emergency slide gates. The inlets are at elevation 2400 feet.

The auxiliary dam in Hot Springs Valley is an earth embankment with a six-inch reinforced concrete apron on the upstream slope connecting with a cut-off wall at the toe. It has an upstream slope of 3 to 1 and a downstream slope of 4 to 1. The maximum height is 55 feet and the crest length 2100 feet. An outlet is located in the left abutment with a discharging capacity of 600 second-feet for release of water to the Borel Power Plant Canal. It consists of two reinforced concrete conduits 10 feet in diameter, extending through the dam and controlled by 10 feet by 10 feet caterpillar type gates located in a gate tower at the upstream end.



ISABELLA RESERVOIR

ON

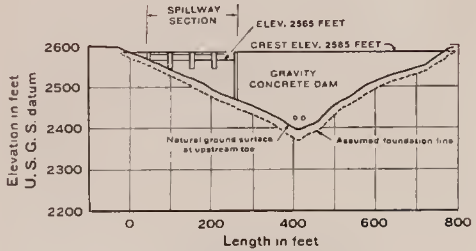
KERN RIVER

dam at the valley crest would be only 55 feet and that some leakage loss would be allowable, the proposed auxiliary dam site was concluded to be more desirable than the site considered near Isabella.

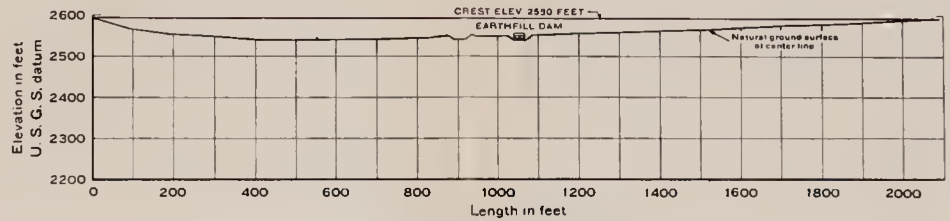
Dams and Appurtenances—The topography of the sites and the general layouts of the proposed dams and appurtenances are shown on Plate LVI, "Isabella Reservoir on Kern River." The main dam has a crest length of 780 feet and a maximum height of 190 feet above stream bed, including five feet of freeboard. It is a concrete gravity type structure, somewhat curved in plan to fit the topography. It has an overflow spillway at the right abutment, having an estimated discharging capacity of 57,000 second-feet or 3.4 times the once-in-25-year flood. The spillway discharge would be controlled by four drum gates 20 feet high by 45 feet long. A lined spillway channel is provided to convey the water to the river channel below the dam.

Reserve space of 67,000 acre-feet, involving a maximum drawdown of nine feet, would be provided for regulation of winter floods to a maximum flow of 7500 second-feet, exceeded once in 100 years on the average. The required capacity for flood regulation is provided by the irrigation outlets. These outlets consist of two 98-inch pipes through the dam, with a combined discharging capacity of 3500 second-feet under a minimum head of 25 feet and 8500 second-feet under a head of 170 feet. The outlets are controlled by needle valves and emergency slide gates. The inlets are at elevation 2400 feet.

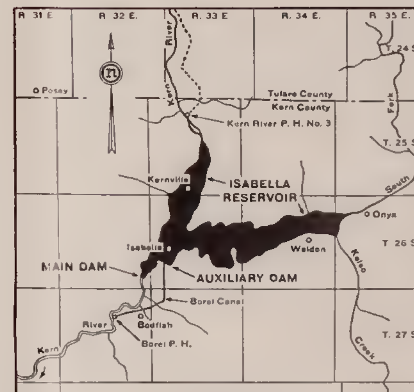
The auxiliary dam in Hot Springs Valley is an earth embankment with a six-inch reinforced concrete apron on the upstream slope connecting with a cut-off wall at the toe. It has an upstream slope of 3 to 1 and a downstream slope of 4 to 1. The maximum height is 55 feet and the crest length 2100 feet. An outlet is located in the left abutment with a discharging capacity of 600 second-feet for release of water to the Borel Power Plant Canal. It consists of two reinforced concrete conduits 10 feet in diameter, extending through the dam and controlled by 10 feet by 10 feet caterpillar type gates located in a gate tower at the upstream end.



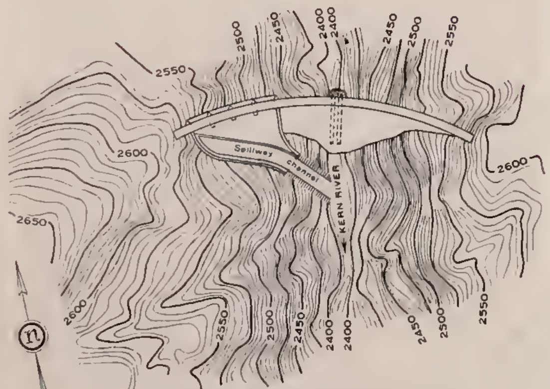
PROFILE OF MAIN DAM
LOOKING UPSTREAM



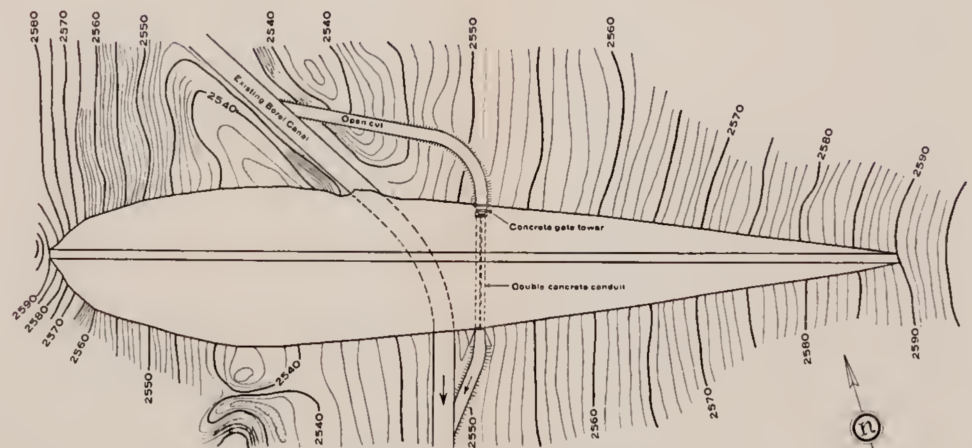
PROFILE OF AUXILIARY DAM
LOOKING UPSTREAM



LOCATION MAP



GENERAL PLAN OF MAIN DAM
FEET
0 200 400



GENERAL PLAN OF AUXILIARY DAM
HOT SPRINGS VALLEY
FEET
0 200 400

ISABELLA RESERVOIR
ON
KERN RIVER

80997

Cost of Isabella Reservoir—The capital and annual costs of Isabella Reservoir, estimated in accord with bases previously presented in this chapter, are set forth in Table 98.

TABLE 98

COST OF ISABELLA RESERVOIR

Height of main concrete dam, 190 feet. Capacity of reservoir, 338,000 acre-feet.
Height of auxiliary earthfill dam, 55 feet.
Capacity of spillway, 57,000 second-feet.
Capacity of irrigation outlets, 3,500 second-feet.
Capacity of outlets, through auxiliary dam, to release water for existing Borel Power Canal, 600 second-feet.

Exploration		$15,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing (including capitalized values of loss of power output of Borel Power Plant)		1,363,000
Main concrete dam—		
Excavation, 52,000 cubic yards at $3.00 to $5.00	$184,000	
Mass concrete, 190,000 cubic yards at $9.00	1,710,000	
Reinforced concrete, 1,200 cubic yards at $19.00 to $30.00	26,000	
Spillway gates	130,000	
Spillway channel	106,000	
Irrigation outlets and sluiceways	113,000	
Drilling, grouting, drains and contraction seals	20,000	
		2,289,000
Auxiliary earthfill dam—		
Excavation, 50,000 cubic yards at $0.50	$25,000	
Earthfill in dam, 370,000 cubic yards at $0.75	277,000	
Reinforced concrete face, 4,000 cubic yards at $16.00	64,000	
Miscellaneous reinforced concrete and cut-off walls, 1,700 cubic yards at $25.00 to $30.00	47,000	
Borel Canal outlet tower, conduit and gates	31,000	
		444,000
Miscellaneous		132,000
Subtotal dams and reservoir		$4,263.000
Administration and engineering at 10 per cent		426,000
Contingencies at 15 per cent		640,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		371,000
Total capital cost of dams and reservoir		$5,700,000
Total annual cost of dams and reservoir		$340,000

Summary of Surface Storage Reservoirs.

A summary of the cost estimates and principal physical features of all of the major surface storage reservoirs of the ultimate State Water Plan for the San Joaquin River Basin is set forth in Table 99. The heights of dams, capacities and capital and gross annual costs of reservoirs and power plants, average annual electric energy outputs and estimated revenues therefrom, net annual costs not covered by revenues from sale of electric energy and average seasonal irrigation yields are included in the tabulation.

UNDERGROUND RESERVOIRS

Utilization of underground storage is growing increasingly important throughout the State. In the upper San Joaquin Valley, the south coastal basin of southern California, Ventura County, the Santa Clara Valley and most of the Central Pacific Coast valleys, underground storage now is being utilized to a large extent. It has been practiced for many years in the upper San Joaquin Valley. The extent and feasibility of this practice has been demonstrated in Chapter IV, where it is shown that, in 1929, the aggregate capacity of wells and pumping plants for the whole area was 20,600 second-feet or 1,236,000 acre-feet per month, if operated continuously. Where suitable underground storage is available and a proper control of draft and replacement is exercised, it is a most flexible, efficient and economical means of conserving and utilizing water over a period of years.

Locations and Capacities of Underground Reservoirs in San Joaquin Valley.

Due to the importance of underground storage, a geologic study was made of the San Joaquin Valley to locate underground storage areas, to estimate their capacity and to determine the practicability of their utilization for the storage and regulation of water supplies in irrigation development. This study reveals that the absorptive areas and available underground storage capacities are large and extensive, particularly in the upper San Joaquin Valley, but limited in their effective utilization due to the lack of readily available surplus water for their charge and recharge. These underground storage reservoir areas are confined to the eastern slope, principally to the alluvial cones and flood plains of the major streams. The surface soil and the geologic formation on the western slope and within the trough of the valley are of such character that no utilizable underground capacity exists. The surface areas of the ground water storage reservoirs and the depths of pervious formations were estimated through field examination of the physical characteristics of surface soils and the application of geologic reasoning, checked and aided as to subsurface characteristics by the penetration records of several hundred wells. The maximum usable storage capacity was limited by economic pumping lift and the availability of ground water storage to the irrigable areas. The locations of the ground water storage reservoirs are shown in Appendix B, "Geology and Underground Water Storage Capacity of San Joaquin Valley."

Results of experimental work furnish a measure for estimating the free water content of various types of alluvial material and soils. The materials logged in the well penetration records available were evaluated and estimates made of the average effective capacity of the soil column per foot of water table lowering. These results were checked with indicated drainage factors obtained by analyses presented in Chapter IV for present developed areas, in which quantities of depletion and water table lowering could be determined. The estimated total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the valley are shown in Table 100. The usable capacities are shown, first, between a depth of 10 feet below ground surface and the underground water level of 1929, and second, between depths of 10 and 50 feet below ground surface. Within some of these areas a greater depth of water table lowering than 50 feet, on the average, would be desirable and probably economically warranted at the end of a long dry period. For this reason, there also is included in the table the estimated underground capacity between the depths of 10 feet below ground surface and the assumed economic limit of pumping lift.

In proportioning the physical works for the ultimate development of the State Water Plan for the lower San Joaquin Valley, the only account taken of the availability of potential underground storage

TER PLAN IN SAN JOAQUIN RIVER BASIN

Total cost		Average annual electric energy output, in kilowatt hours (reservoir operated primarily for irrigation)	Value of electric energy per kilowatt hour, in mills	Average annual revenue from sale of electric energy	Average net annual cost, not covered by revenue from sale of electric energy	Average seasonal irrigation yield, in acre-feet
Capital	Annual					
$7,400,000	$441,000				$441,000	(1)163,000
8,600,000	517,000				517,000	(1), (2)150,000
						(1), (3)294,000
7,600,000	452,000				452,000	(1)98,000
26,200,000	1,657,000	240,000,000	3.00	$720,000	937,000	(5)887,000
32,500,000	2,074,000	365,000,000	3.00	1,095,000	979,000	(5)1,303,000
						(5), (6)728,000
2,600,000	155,000				155,000	(5)53,000
3,300,000	200,000				200,000	(5)45,000
14,500,000	885,000	23,000,000	3.50	80,000	805,000	(5), (6)1,726,000
(8)15,500,000	(6)1,062,000	(9)105,000,000	3.50	(9)367,000	(9)695,000	(9), (6)602,000
11,600,000	742,000	100,500,000	2.00	201,000	541,000	(5), (6)1,764,000
						(5), (6)435,000
2,900,000	171,000				171,000	(5), (6), (10)128,000
5,700,000	340,000				340,000	(5), (6)670,000

per month, if operated continuously. Where suitable underground storage is available and a proper control of draft and replacement is exercised, it is a most flexible, efficient and economical means of conserving and utilizing water over a period of years.

Locations and Capacities of Underground Reservoirs in San Joaquin Valley.

Due to the importance of underground storage, a geologic study was made of the San Joaquin Valley to locate underground storage areas, to estimate their capacity and to determine the practicability of their utilization for the storage and regulation of water supplies in irrigation development. This study reveals that the absorptive areas and available underground storage capacities are large and extensive, particularly in the upper San Joaquin Valley, but limited in their effective utilization due to the lack of readily available surplus water for their charge and recharge. These underground storage reservoir areas are confined to the eastern slope, principally to the alluvial cones and flood plains of the major streams. The surface soil and the geologic formation on the western slope and within the trough of the valley are of such character that no utilizable underground capacity exists. The surface areas of the ground water storage reservoirs and the depths of pervious formations were estimated through field examination of the physical characteristics of surface soils and the application of geologic reasoning, checked and aided as to subsurface characteristics by the penetration records of several hundred wells. The maximum usable storage capacity was limited by economic pumping lift and the availability of ground water storage to the irrigable areas. The locations of the ground water storage reservoirs are shown in Appendix B, "Geology and Underground Water Storage Capacity of San Joaquin Valley."

Results of experimental work furnish a measure for estimating the free water content of various types of alluvial material and soils. The materials logged in the well penetration records available were evaluated and estimates made of the average effective capacity of the soil column per foot of water table lowering. These results were checked with indicated drainage factors obtained by analyses presented in Chapter IV for present developed areas, in which quantities of depletion and water table lowering could be determined. The estimated total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the valley are shown in Table 100. The usable capacities are shown, first, between a depth of 10 feet below ground surface and the underground water level of 1929, and second, between depths of 10 and 50 feet below ground surface. Within some of these areas a greater depth of water table lowering than 50 feet, on the average, would be desirable and probably economically warranted at the end of a long dry period. For this reason, there also is included in the table the estimated underground capacity between the depths of 10 feet below ground surface and the assumed economic limit of pumping lift.

In proportioning the physical works for the ultimate development of the State Water Plan for the lower San Joaquin Valley, the only account taken of the availability of potential underground storage

TABLE 99

SUMMARY OF COSTS AND PRINCIPAL PHYSICAL FEATURES OF SURFACE STORAGE UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Name of reservoir or site	Stream	Height of dam, in feet	Capacity of reservoir, in acre-feet	Power plant			Cost of reservoir		Cost of power plant		Total cost		Average annual electric energy output, in kilowatt hours (reservoir operated primarily for irrigation)	Value of electric energy per kilowatt hour, in mills	Average annual revenue from sale of electric energy	Average net annual cost, not covered by revenue from sale of electric energy	Average seasonal irrigation yield, in acre-feet
				Installed capacity, in kilovolt amperes	Power factor	Load factor	Capital	Annual	Capital	Annual	Capital	Annual					
Nashville	Cosumnes River	270	281,000	0			$7,400,000	$441,000			$7,400,000	$441,000				$441,000	(1)163,000
Ione	Dry Creek	120	610,000	0			8,600,000	517,000			8,600,000	517,000				517,000	(1), (2)150,000
Pardee (constructed)	Mokelumne River	343	222,000	18,750	0 80	1.00											(1), (3)294,000
Valley Springs	Calaveras River	200	(4)325,000	0			7,600,000	452,000			7,600,000	452,000				452,000	(1)98,000
Melones	Stanislaus River	460	1,090,000	68,000	0 80	1 00	22,200,000	1,334,000	$4,000,000	$323,000	26,200,000	1,657,000	240,000,000	3 00	$720,000	937,000	(5)887,000
Don Pedro	Tuolumne River	455	1,000,000	120,000	.80	1.00	26,500,000	1,590,000	6,000,000	484,000	32,500,000	2,074,000	365,000,000	3.00	1,095,000	979,000	(5)1,303,000
Exchequer (constructed)	Merced River	307	279,000	31,250	.80	1.00											(5), (6)728,000
Buchanan	Chowchilla River	147	84,000	0			2,600,000	155,000			2,600,000	155,000				155,000	(5)53,000
Windy Gap	Fresno River	206	62,000	0			3,300,000	200,000			3,300,000	200,000				200,000	(5)45,000
Friant	San Joaquin River	252	(7)400,000	10,000 (8)30,000	.80 .80	1.00 1.00	14,000,000	840,000	500,000 (8)1,500,000	45,000 (8)222,000	14,500,000 (8)15,500,000	885,000 (8)1,062,000	23,000,000 (8)105,000,000	3 50 3.50	80,000 (8)367,000	805,000 (9)695,000	(5), (6)1,726,000 (9), (6)602,000
Pine Flat	Kings River	274	400,000	40,000	.80	1.00	9,600,000	574,000	2,000,000	168,000	11,600,000	742,000	100,500,000	2 00	201,000	541,000	(5), (6)1,764,000
Ward	Kaweah River	No reservoir at this site included in State plan.															(5), (6)435,000
Pleasant Valley	Tule River	125	39,000	0			2,900,000	171,000			2,900,000	171,000				171,000	(5), (6), (10)128,000
Isabella	Kern River	190	338,000	0			5,700,000	340,000			5,700,000	340,000				340,000	(5), (6)670,000

(1) Average for 11-year period, 1918-1929.
(2) Includes spill from Pardee Reservoir on Mokelumne River.
(3) Excludes 200,000,000 gallons per day for East Bay Municipal Utility District.
(4) Includes 165,000 acre-feet of storage space, reserved solely for flood control.
(5) Average for 40-year period, 1889-1929.
(6) Includes yield available for and utilizable by ground-water storage.
(7) Net utilizable capacity, 270,000 acre-feet.
(8) Immediate initial development. Life of power plant and period of amortization assumed as 10 years.
(9) Average for 12-year period, 1917-1929.
(10) Includes run-off from South Fork.

TABLE 100

UTILIZABLE UNDERGROUND STORAGE CAPACITY IN SAN JOAQUIN VALLEY BY HYDROGRAPHIC DIVISIONS

Hydrographic division	Gross absorptive area, in acres	Usable underground capacity, in acre-feet		
		Between a depth of 10 feet below ground surface and ground water levels of 1929	Between depths of 10 and 50 feet below ground surface	Between a depth of 10 feet below ground surface and assumed economic limit of pumping lift
1	525,000	3,707,000	3,000,000	3,750,000
2	322,000	2,224,000	1,900,000	3,650,000
3	308,000	1,212,000	1,800,000	2,300,000
4	996,000	1,097,000	6,000,000	8,000,000
5				
6	281,000	760,000	2,000,000	2,300,000
7				
8	146,000	0	850,000	850,000
9	215,000	0	1,260,000	1,260,000
10				
11	83,000	0	470,000	470,000
12	104,000	160,000	420,000	520,000
13	10,000	Not utilizable		

capacity was in the absorptive area to be ultimately served in Hydrographic Division 8 with Merced River water.* However, if underground reservoirs in other areas were operated in conjunction with surface storage, a greater use could be made of the run-off of the tributary streams. In the upper San Joaquin Valley, except in Hydrographic Division 6 (Madera Unit), full account was taken of the available underground capacity in the design of the works to serve this region. Both local and imported supplies must be husbanded if the fullest practicable utilization for beneficial purposes and maximum economy are to be attained. To accomplish the desired results would require the operation of the underground reservoirs in a specific manner similar to that of surface reservoirs. A large portion of the gross draft upon the ground water would be through the medium of privately owned pumping plants, and, in order to maintain a balance in supply and draft over long periods throughout the area, it would be necessary that works for the distribution of surplus waters and pumping equipment in strategic locations be under the control of recognized local public agencies.

It is demonstrated in Chapter VII that the utilization of this underground capacity affords the cyclic storage necessary in the plan for the full practical ultimate development of the eastern slope of the upper San Joaquin Valley. Furthermore, when operated in conjunction with surface regulation and distribution, it is shown to result in the cheapest, most flexible and dependable plan of any that has been suggested or investigated to furnish the required water supply for this region.

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–31 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to provide the required water supplies with the available run-off from 1929 to 1931, including the dry season 1930–31, the studies presented in Appendix D show that it would be necessary to utilize the available underground storage in several additional areas in the lower San Joaquin Valley and also in Hydrographic Division No. 6 of the upper San Joaquin Valley.

Cost of Utilization of Underground Reservoirs.

Contributions to ground water reservoirs are made by absorption of surface run-off in natural stream channels and spreading areas, from artificial conveyance channels and through irrigation applications in excess of net use, which may or may not involve expenditure of funds. The extraction of ground water by means of wells and pumping plants constitutes the principal item of expense in the utilization of ground water. The determination of pumping costs for a particular area is the principal element in a study of the economics of ground water utilization and is, in many cases, one of the important factors governing the economic capacity of surface storage regulation on streams supplying that area. The costs of ground water pumping, in the San Joaquin Valley, have been estimated by analyses of the costs and performance of modern pumping plants under actual operating conditions.

Cost of Pumping from Wells.

Capital Cost—The installation cost of pumping plants and wells varies with the capacity and lift. The capacity varies with the extent of the area to be served. A well established criterion is that the plant should have sufficient capacity to deliver at least six inches in depth per month to the area served. This criterion establishes about the minimum cost of installation for a given area. This capacity requires five months of continuous operation to obtain a gross delivery of 2.5 acre-feet per acre. Table 101 sets forth in column (6) an estimate of the capital costs of pumping plants varying in capacity from 225 to 1125 gallons per minute and for total lifts varying from 25 to 250 feet. The costs of wells have been based on the use of 12-gage hard red steel casing for 10 and 12-inch diameter wells and on 10-gage casing for larger sizes. The depth of each well was assumed to be 100 feet more than the total lift. This assumption is applicable in delta areas. In areas away from streams, much greater depths are required. Estimates of the costs of pumping equipment are based on the direct-connected, electrically-driven well turbine type pump installations. The usual diameter of the well casing and the installed horsepower of the motor are set forth in columns (3) and (4), respectively, of the tabulation for each of the various capacities and heights of lift considered.

Items of Annual Cost—The annual cost of ground water pumping varies with the period of operation, efficiency of the pumping plant, capacity and lift. The items making up the annual cost are plant depreciation, interest on the investment, taxes and insurance, operation, maintenance and power. In this analysis all charges except power are considered as fixed although depreciation and operation and maintenance vary from year to year depending on the period of operation.

Plant Depreciation—The normal useful life of a well and pumphouse is estimated at from 25 to 30 years. The life of a motor is estimated as 20 years and the useful life of a pump as 15 years. Many motors have been in nearly continuous service for 25 years. Pumps used under conditions where corrosive chemicals or sand are carried in the water may have a life of only five years. On the other hand, where clean pure water is pumped, a life of from 25 to 30 years is not

Total height of lift, in feet	year		8 months per year			9 months per year		
		Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total
(1)		(33)	(34)	(35)	(36)	(37)	(38)	(39)
25	7	5.8	1.9	3.7	5.6	1.7	3.6	5.3
	8	5.3	1.3	3.7	5.0	1.1	3.7	4.8
	3	4.5	1.0	3.3	4.3	0.9	3.3	4.2
	4	4.3	0.8	3.4	4.2	0.7	3.3	4.0
	1	4.0	0.7	3.1	3.8	0.7	3.0	3.7
50	8	5.4	1.4	3.7	5.1	1.2	3.7	4.9
	4	4.5	0.9	3.4	4.3	0.8	3.3	4.1
	1	3.9	0.7	3.0	3.7	0.6	3.0	3.6
	7	3.3	0.6	2.6	3.2	0.5	2.6	3.1
	6	3.2	0.5	2.6	3.1	0.5	2.6	3.1
75	3	4.7	1.2	3.3	4.5	1.1	3.3	4.4
	1	4.0	0.8	3.0	3.8	0.7	3.0	3.7
	6	3.2	0.6	2.5	3.1	0.5	2.5	3.0
	4	2.9	0.5	2.4	2.9	0.4	2.4	2.8
	4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
100	4	4.7	1.1	3.4	4.5	1.0	3.3	4.3
	7	3.5	0.7	2.6	3.3	0.6	2.6	3.2
	4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
	2	2.6	0.4	2.2	2.6	0.3	2.1	2.4
150	1	4.2	1.0	3.0	4.0	0.9	3.0	3.9
	4	3.1	0.6	2.4	3.0	0.5	2.4	2.9
	3	2.8	0.4	2.2	2.6	0.4	2.2	2.6
	2	2.6	0.4	2.1	2.5	0.3	2.1	2.4
	1	2.5	0.3	2.1	2.4	0.3	2.1	2.4
200	7	3.8	0.9	2.6	3.5	0.8	2.6	3.4
	4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	2	2.7	0.4	2.1	2.5	0.4	2.1	2.5
	1	2.5	0.3	2.1	2.4	0.3	2.0	2.3
	9	2.2	0.3	1.9	2.2	0.3	1.8	2.1
250	6	3.6	0.9	2.6	3.5	0.8	2.6	3.4
	2	2.8	0.5	2.2	2.7	0.5	2.1	2.6
	1	2.5	0.4	2.1	2.5	0.3	2.1	2.4
	9	2.3	0.3	1.9	2.2	0.3	1.8	2.1
	8	2.1	0.3	1.8	2.1	0.2	1.8	2.0

Cost of Utilization of Underground Reservoirs.

Contributions to ground water reservoirs are made by absorption of surface run-off in natural stream channels and spreading areas, from artificial conveyance channels and through irrigation applications in excess of net use, which may or may not involve expenditure of funds. The extraction of ground water by means of wells and pumping plants constitutes the principal item of expense in the utilization of ground water. The determination of pumping costs for a particular area is the principal element in a study of the economics of ground water utilization and is, in many cases, one of the important factors governing the economic capacity of surface storage regulation on streams supplying that area. The costs of ground water pumping, in the San Joaquin Valley, have been estimated by analyses of the costs and performance of modern pumping plants under actual operating conditions.

Cost of Pumping from Wells.

Capital Cost—The installation cost of pumping plants and wells varies with the capacity and lift. The capacity varies with the extent of the area to be served. A well established criterion is that the plant should have sufficient capacity to deliver at least six inches in depth per month to the area served. This criterion establishes about the minimum cost of installation for a given area. This capacity requires five months of continuous operation to obtain a gross delivery of 2.5 acre-feet per acre. Table 101 sets forth in column (6) an estimate of the capital costs of pumping plants varying in capacity from 225 to 1125 gallons per minute and for total lifts varying from 25 to 250 feet. The costs of wells have been based on the use of 12-gage hard red steel casing for 10 and 12-inch diameter wells and on 10-gage casing for larger sizes. The depth of each well was assumed to be 100 feet more than the total lift. This assumption is applicable in delta areas. In areas away from streams, much greater depths are required. Estimates of the costs of pumping equipment are based on the direct-connected, electrically-driven well turbine type pump installations. The usual diameter of the well casing and the installed horsepower of the motor are set forth in columns (3) and (4), respectively, of the tabulation for each of the various capacities and heights of lift considered.

Items of Annual Cost—The annual cost of ground water pumping varies with the period of operation, efficiency of the pumping plant, capacity and lift. The items making up the annual cost are plant depreciation, interest on the investment, taxes and insurance, operation, maintenance and power. In this analysis all charges except power are considered as fixed although depreciation and operation and maintenance vary from year to year depending on the period of operation.

Plant Depreciation—The normal useful life of a well and pumphouse is estimated at from 25 to 30 years. The life of a motor is estimated as 20 years and the useful life of a pump as 15 years. Many motors have been in nearly continuous service for 25 years. Pumps used under conditions where corrosive chemicals or sand are carried in the water may have a life of only five years. On the other hand, where clean pure water is pumped, a life of from 25 to 30 years is not

TABLE 101

COST OF GROUND WATER PUMPING

Total height of lift, in feet (1)	Capacity of plant, in gallons per minute (2)	Usual diameter of well casing, in inches (3)	Usual installed size of motor, in horsepower (4)	Average overall plant efficiency, in per cent (5)	Capital cost of installation. Well, motor, pump, building, etc. (6)	Average annual fixed charges at 14 per cent of capital cost (7)	Acre-feet per month of thirty 24-hour days (8)	Acre-feet per month (9)	Kilowatt-hours per month (10)	Annual power demand charge, S-P-2 Schedule (11)	Energy charge for one month, S-P-2 Schedule (12)
25	225	10	3.0	40	$800	$112	30	750	1,020	$15.00	$25.23
	450	12	7½	43	1,100	154	60	1,500	3,570	37.50	51.25
	675	12-14	10	44	1,300	182	90	2,250	5,240	50.00	68.16
	900	14	15	45	1,400	196	120	3,000	6,830	67.50	92.97
	1,125	16	15	46	1,600	224	150	3,750	8,350	67.50	106.65
50	225	10	7½	43	1,200	168	30	1,500	3,570	37.50	51.25
	450	12	15	45	1,600	224	60	3,000	6,830	67.50	92.97
	675	12-14	20	49	1,800	252	90	4,500	9,410	85.00	126.69
	900	14	25	50	1,900	266	120	6,000	12,290	102.50	145.82
	1,125	16	30	51	2,200	308	150	7,500	15,070	120.00	177.56
75	225	10	10	44	1,600	224	30	2,250	5,240	50.00	68.16
	450	12	20	49	2,000	280	60	4,500	9,410	85.00	126.69
	675	12-14	25	50	2,200	308	90	6,750	13,630	102.50	158.14
	900	14	30	51	2,400	336	120	9,000	18,080	120.00	201.64
	1,125	16	40	52	2,700	378	150	11,250	22,160	155.00	253.28
100	225	10	15	45	1,900	266	30	3,000	6,830	67.50	92.97
	450	12	25	50	2,400	336	60	6,000	12,290	102.50	145.82
	675	12-14	30	51	2,700	378	90	9,000	18,080	120.00	201.64
	900	14	40	52	2,800	392	120	12,000	23,640	155.00	265.12
	1,125	16	50	54	3,100	434	150	15,000	28,490	190.00	299.70
150	225	10	20	49	2,500	350	30	4,500	9,410	85.00	126.69
	450	12	30	51	3,100	434	60	9,000	18,080	120.00	201.64
	675	12-14	50	54	3,400	476	90	13,500	25,610	190.00	278.33
	900	14	60	55	3,600	504	120	18,000	33,530	225.00	354.97
	1,125	16	75	56	4,000	560	150	22,500	41,160	277.50	438.08
200	225	10	25	50	3,200	448	30	6,000	12,290	102.50	145.82
	450	12	40	52	3,700	518	60	12,000	23,640	155.00	265.12
	675	12-14	60	55	4,100	574	90	18,000	33,530	225.00	354.97
	900	14	75	56	4,500	630	120	24,000	43,910	277.50	458.70
	1,125	16	100	58	5,000	700	150	30,000	53,000	365.00	516.00
250	225	10	30	51	3,800	532	30	7,500	15,070	120.00	177.56
	450	12	50	54	4,400	616	60	15,000	28,450	190.00	299.70
	675	12-14	75	50	4,900	686	90	22,500	41,160	277.50	438.08
	900	14	100	55	5,400	756	120	30,000	53,000	365.00	516.00
	1,125	16	125	60	6,000	840	150	37,500	64,030	452.50	629.40

Annual cost per foot acre-foot, in cents

Total height of lift, in feet (1)	Capacity (2)	1 month per year: Fixed charges (13)	Power charges (14)	Total (15)	2 months per year: Fixed charges (16)	Power charges (17)	Total (18)	3 months per year: Fixed charges (19)	Power charges (20)	Total (21)	4 months per year: Fixed charges (22)	Power charges (23)	Total (24)
25	225	14.9	5.4	20.3	7.5	4.4	11.9	5.0	4.0	9.0	3.7	3.9	7.6
	450	10.3	5.9	16.2	5.1	4.7	9.8	3.4	4.2	7.6	2.6	4.0	6.6
	675	8.1	5.2	13.3	4.0	4.1	8.1	2.7	3.7	6.4	2.0	3.6	5.6
	900	6.5	5.4	11.9	3.3	4.2	7.5	2.2	3.9	6.1	1.6	3.7	5.3
	1,125	6.0	4.6	10.6	3.0	3.7	6.7	2.0	3.4	5.4	1.5	3.3	4.8
50	225	11.2	5.9	17.1	5.6	4.7	10.3	3.7	4.2	7.9	2.8	4.0	6.8
	450	7.5	5.4	12.9	3.7	4.2	7.9	2.5	3.9	6.4	1.9	3.7	5.6
	675	5.6	4.7	10.3	2.8	3.8	6.8	1.9	3.4	5.3	1.4	3.3	4.7
	900	4.4	4.1	8.5	2.2	3.3	5.5	1.5	3.0	4.5	1.1	2.9	4.0
	1,125	4.1	4.0	8.1	2.0	3.2	5.2	1.4	2.9	4.3	1.0	2.8	3.8
75	225	10.0	5.2	15.2	5.0	4.1	9.1	3.3	3.7	7.0	2.5	3.6	6.1
	450	6.2	4.7	10.9	3.1	3.8	6.0	2.1	3.4	5.5	1.6	3.3	4.9
	675	4.6	3.9	8.5	2.3	3.1	5.4	1.5	2.8	4.3	1.2	2.7	3.9
	900	3.7	3.6	7.3	1.9	2.9	4.8	1.2	2.7	3.9	0.9	2.6	3.5
	1,125	3.4	3.6	7.0	1.7	2.9	4.6	1.1	2.7	3.8	0.8	2.6	3.4
100	225	8.9	5.4	14.3	4.4	4.2	8.6	3.0	3.0	6.0	2.2	3.7	5.9
	450	5.6	4.1	9.7	2.8	3.3	6.1	1.9	3.0	4.9	1.4	2.9	4.3
	675	4.2	3.6	7.8	2.1	2.9	5.0	1.4	2.7	4.1	1.0	2.6	3.6
	900	3.3	3.5	6.8	1.6	2.9	4.5	1.1	2.6	3.7	0.8	2.5	3.3
	1,125	2.9	3.3	6.2	1.4	2.6	4.0	1.0	2.4	3.4	0.7	2.3	3.0
150	225	7.8	4.7	12.5	3.9	3.8	7.7	2.6	3.4	6.0	1.9	3.3	5.2
	450	4.8	3.6	8.4	2.4	2.9	5.3	1.6	2.7	4.3	1.2	2.6	3.8
	675	3.5	3.5	7.0	1.8	2.8	4.6	1.2	2.5	3.7	0.9	2.4	3.3
	900	2.8	3.2	6.0	1.4	2.6	4.0	0.9	2.4	3.3	0.7	2.3	3.0
	1,125	2.5	3.2	5.7	1.2	2.6	3.8	0.8	2.4	3.2	0.6	2.3	2.9
200	225	7.5	4.1	11.6	3.7	3.3	7.0	2.5	3.0	5.5	1.9	2.9	4.8
	450	4.3	3.5	7.8	2.2	2.9	5.1	1.4	2.6	4.0	1.1	2.5	3.6
	675	3.2	3.2	6.4	1.6	2.6	4.2	1.1	2.4	3.5	0.8	2.3	3.1
	900	2.6	3.1	5.7	1.3	2.5	3.8	0.9	2.3	3.2	0.7	2.2	2.9
	1,125	2.3	2.9	5.2	1.2	2.3	3.5	0.8	2.1	2.9	0.6	2.0	2.6
250	225	7.1	4.0	11.1	3.5	3.2	6.7	2.4	2.9	5.3	1.8	2.8	4.6
	450	4.1	3.3	7.4	2.1	2.6	4.7	1.4	2.4	3.8	1.0	2.3	3.3
	675	3.0	3.2	6.2	1.5	2.6	4.1	1.0	2.4	3.4	0.8	2.3	3.1
	900	2.5	2.9	5.4	1.3	2.3	3.6	0.8	2.1	2.9	0.6	2.0	2.6
	1,125	2.2	2.9	5.1	1.1	2.3	3.4	0.7	2.1	2.8	0.6	2.0	2.6

Total height of lift, in feet (1)	Capacity (2)	5 months per year: Fixed charges (25)	Power charges (26)	Total (27)	6 months per year: Fixed charges (28)	Power charges (29)	Total (30)	7 months per year: Fixed charges (31)	Power charges (32)	Total (33)	8 months per year: Fixed charges (34)	Power charges (35)	Total (36)	9 months per year: Fixed charges (37)	Power charges (38)	Total (39)
25	225	3.0	3.8	6.8	2.5	3.7	6.2	2.1	3.7	5.8	1.9	3.7	5.6	1.7	3.6	5.3
	450	2.1	3.9	6.0	1.7	3.8	5.5	1.5	3.8	5.3	1.3	3.7	5.0	1.1	3.7	4.5
	675	1.6	3.5	5.1	1.3	3.4	4.7	1.2	3.3	4.5	1.0	3.3	4.3	0.9	3.3	4.2
	900	1.3	3.5	4.8	1.1	3.5	4.6	0.9	3.4	4.3	0.8	3.4	4.2	0.7	3.3	4.0
	1,125	1.2	3.2	4.4	1.0	3.1	4.1	0.9	3.1	4.0	0.7	3.1	3.8	0.7	3.0	3.7
50	225	2.2	3.9	6.1	1.9	3.8	5.7	1.6	3.8	5.4	1.4	3.7	5.1	1.2	3.7	4.9
	450	1.5	3.5	5.0	1.2	3.5	4.7	1.1	3.4	4.5	0.9	3.4	4.3	0.8	3.3	4.1
	675	1.1	3.2	4.3	0.9	3.1	4.0	0.8	3.1	3.9	0.7	3.0	3.7	0.6	3.0	3.6
	900	0.9	2.8	3.7	0.7	2.7	3.4	0.6	2.7	3.3	0.6	2.6	3.2	0.5	2.6	3.1
	1,125	0.8	2.7	3.5	0.7	2.6	3.3	0.0	2.6	3.2	0.5	2.6	3.1	0.5	2.6	3.1
75	225	2.0	3.5	5.5	1.7	3.4	5.1	1.4	3.[illegible]	4.7	1.2	3.3	4.5	1.1	3.3	4.4
	450	1.2	3.2	4.4	1.0	3.1	4.1	0.0	3.1	4.0	0.8	3.0	3.8	0.7	3.0	3.7
	675	0.9	2.6	3.5	0.8	2.6	3.4	0.0	2.6	3.2	0.6	2.5	3.1	0.5	2.5	3.0
	900	0.7	2.5	3.2	0.6	2.5	3.1	0.5	2.4	2.9	0.5	2.4	2.9	0.4	2.4	2.8
	1,125	0.7	2.5	3.2	0.6	2.5	3.1	0.5	2.4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
100	225	1.8	3.5	5.3	1.5	3.5	5.0	1.3	3.4	4.7	1.1	3.4	4.5	1.0	3.3	4.3
	450	1.1	2.8	3.9	0.9	2.7	3.6	0.8	2.7	3.5	0.7	2.6	3.3	0.6	2.6	3.2
	675	0.8	2.5	3.3	0.7	2.5	3.2	0.6	2.4	3.0	0.5	2.4	2.0	0.5	2.4	2.9
	900	0.7	2.5	3.2	0.5	2.4	2.9	0.5	2.1	2.9	0.4	2.4	2.8	0.4	2.4	2.8
	1,125	0.6	2.3	2.9	0.5	2.2	2.7	0.4	2.2	2.6	0.4	2.2	2.6	0.3	2.1	2.4
150	225	1.6	3.2	4.8	1.3	3.1	4.4	1.1	3.1	4.2	1.0	3.0	4.0	0.9	3.0	3.9
	450	1.0	2.5	3.5	0.8	2.5	3.3	0.7	2.4	3.1	0.6	2.4	3.0	0.5	2.4	2.9
	675	0.7	2.3	3.0	0.6	2.3	2.9	0.5	2.3	2.8	0.4	2.2	2.6	0.4	2.2	2.6
	900	0.6	2.2	2.8	0.5	2.2	2.7	0.4	2.2	2.6	0.4	2.1	2.5	0.3	2.1	2.4
	1,125	0.5	2.2	2.7	0.4	2.2	2.6	0.4	2.1	2.5	0.3	2.1	2.4	0.3	2.1	2.4
200	225	1.5	2.8	4.3	1.2	2.7	3.9	1.1	2.7	3.8	0.9	2.6	3.5	0.8	2.6	3.4
	450	0.9	2.5	3.4	0.7	2.4	3.1	0.6	2.4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	675	0.6	2.2	2.8	0.5	2.2	2.7	0.5	2.2	2.7	0.4	2.1	2.5	0.4	2.1	2.5
	900	0.5	2.1	2.6	0.4	2.1	2.5	0.4	2.1	2.5	0.3	2.1	2.4	0.3	2.0	2.3
	1,125	0.5	2.0	2.5	0.4	1.9	2.3	0.3	1.9	2.2	0.3	1.9	2.2	0.3	1.8	2.1
250	225	1.4	2.7	4.1	1.2	2.6	3.8	1.0	2.6	3.6	0.9	2.6	3.5	0.8	2.6	3.4
	450	0.8	2.3	3.1	0.7	2.2	2.9	0.6	2.2	2.8	0.5	2.2	2.7	0.5	2.1	2.6
	675	0.6	2.2	2.8	0.5	2.2	2.7	0.4	2.1	2.5	0.4	2.1	2.5	0.3	2.1	2.4
	900	0.5	2.0	2.5	0.4	1.9	2.3	0.4	1.9	2.3	0.3	1.9	2.3	0.3	1.8	2.1
	1,125	0.4	1.9	2.3	0.4	1.9	2.3	0.3	1.8	2.1	0.3	1.8	2.1	0.2	1.8	2.0

unusual. The average life of the entire plant is estimated herein at 18 years. With this estimated average life, the annual depreciation on a 4 per cent sinking fund basis amounts to 3.9 per cent of the capital cost.

Interest—With depreciation allowed for on a sinking fund basis, interest on the full amount of the initial investment is a proper fixed annual charge. In making an estimate of annual costs on the basis of private financing, an interest rate of 6 per cent has been used.

Taxes and Insurance—It is not possible to arrive at an exact value for taxes because of lack of information on the methods used by various county assessors in determining assessed valuations of wells and pumping plants. An annual amount equal to 1.1 per cent of the capital cost, however, is believed to be a fair average allowance for taxes and insurance.

Operation and Maintenance—This item includes repairs, lubrication and attendance. The average annual repair charges on electrically-driven pumping plants may vary from $0.50 to $5.00 per motor horsepower, depending on the period of operation and speed of the unit and to some degree on the size of the motor. The cost of lubricants varies from $0.005 to $0.01 per hour of operation. Attendance consumes a very small fraction of the irrigator's time. The total annual cost of operation and maintenance varies from 1 to 3 per cent of the capital cost of the plant. The latter value has been used herein, in order to insure an ample allowance for repairs and replacements.

Total Annual Fixed Charges—These include all of the foregoing items which are summarized in per cent of capital cost as follows:

Depreciation	3.9 per cent
Interest	6.0 per cent
Taxes and insurance	1.1 per cent
Operation and maintenance	3.0 per cent
Total	14.0 per cent

Based on 14 per cent of capital cost, the fixed annual charges for all of the various plants considered have been set forth in column (7) of Table 101.

Plant Efficiencies—Efficiencies vary with both the capacity of the plant and the total lift. Better efficiencies are obtained with large plants and high lifts. The repair charges used in the estimated costs for operation and maintenance include a sufficient amount to replace or rebuild worn pump runners and bearings. Minor ground water fluctuations sometimes result in the pump operating at speeds which do not give maximum efficiencies. Large fluctuations covering long periods can be compensated for by changes in the number or size of runners and in the size of motor. Column (5) of Table 101 sets forth an estimate of the long time overall average operating efficiency for a plant with each of the various capacities and heights of lift considered.

Power Costs—For each of the various installations shown in Table 101, there are set forth in columns (8), (9) and (10), respectively, the acre-feet pumped per month, the acre-feet feet per month and the kilowatt hours consumed per month based on the plant efficiencies given in column (5).

In a decision of the Railroad Commission of California, No. 24809, May 24, 1932, power schedule S-P-2, applicable to irrigation pumping by individual users in the territory served by San Joaquin Light and Power Corporation, was adopted. This schedule was used in estimating power costs herein. It provides for intermittent or seasonal use of energy. The total power charge consists of an annual demand charge of $5.00 per horsepower per year up to 10 horsepower of connected load and $3.50 per horsepower of connected load for all over 10 horsepower, and a graduated energy charge varying in price per kilowatt-hour with the connected load and period of operation. The schedule for energy charges is as follows:

	Rate per k.w.h. for monthly consumption of			
H.p. of connected load	*First 50 k.w.h. per h.p.*	*Next 50 k.w.h. per h.p.*	*Next 150 k.w.h. per h.p.*	*All over 250 k.w.h. per h.p.*
2–4	4.0 cents	2.2 cents	1.2 cents	0.9 cents
5–9	3.9	2.1	1.2	0.9
10–24	3.4	2.0	1.1	0.9
25–49	2.9	1.9	1.0	0.8
50–99	2.5	1.7	1.0	0.75
100–249	2.2	1.5	0.9	0.7
250–499	2.0	1.3	0.8	0.65
500–999	1.9	1.2	0.8	0.6
1000–2499	1.8	1.1	0.8	0.6
2500 and over	1.7	1.0	0.8	0.6

Columns (11) and (12) in Table 101 set forth, for each installation, the annual demand charge and the energy charge for one month's continuous operation. Actual operation may or may not be continuous. If not continuous, the average cost per kilowatt-hour for the month would be greater.

Total Annual Costs Per Foot Acre-foot—Based on all of the foregoing values, the total annual costs per foot acre-foot, including both fixed and power charges for each installation considered for periods of operation varying from one to nine months per year, have been computed and set forth in columns (13) to (39), inclusive, of Table 101. A study of the table reveals how variable the costs per foot acre-foot may be and demonstrates the relative effect of the different factors. Based upon the furnishing of a full supply of 2.5 acre-feet per acre per season and a total pumping lift of 50 feet, a pumping plant with a required capacity of 450 gallons per minute to serve an area of 120 acres would require five months' pumping. The pumping cost per foot acre-foot would be 1.5 cents for fixed charges and 3.5 cents for power charges or a total of 5.0 cents. If the lift were 75 feet, fixed charges would be 1.2 cents, power charges 3.2 cents and the total cost 4.4 cents; if 100 feet, 1.1 cents, 2.8 cents and 3.9 cents, respectively, per foot acre-foot. If only a 60 per cent supply were pumped from ground water, the charges for a 50-foot lift would be 2.5 cents, 3.9 cents and 6.4 cents, respectively; for 75 feet, 2.1 cents, 3.4 cents and 5.5 cents; and, for 100 feet, 1.9 cents, 3.0 cents and 4.9 cents. Plants of twice this capacity for twice the area, have charges about 25 per cent lower. Plants of twice the lift also have charges about 25 per cent lower and so on. For estimating pumping costs in the upper San Joaquin Valley, general average values of 2.0 cents per foot acre-foot for fixed charges and 3.0 cents per foot acre-foot for power charges or a total of 5.0 cents per foot acre-foot have been used.

CONVEYANCE UNITS

The proposed conveyance units of the ultimate State Water Plan in the San Joaquin River Basin are designed primarily to bring necessary water supplies from the Sacramento River Basin to the San Joaquin Valley to supplement the available local water supplies in and furnish the ultimate water requirements of the San Joaquin River Basin. In the formulation of a plan for conveyance of Sacramento River water to the San Joaquin Valley, many alternate plans were investigated. These alternate plans were based upon an imported supply of 3000 second-feet to supply lands on the eastern slope of the upper San Joaquin Valley in accord with the plan for complete initial development. The ultimate plan provides for the importation of 8000 second-feet which, together with the development of local sources of supply, would make available a water supply for practically all of the net irrigable area in the San Joaquin Valley. However, the results of the economic studies for the initial capacity are conclusive also with respect to ultimate capacity.

Among the plans investigated was one with a gravity canal extending from the Feather River to Kern River. A second plan investigated, which would involve the exchange of water supplies on the upper San Joaquin River, was a conduit extending from the Folsom Reservoir on the American River to Mendota on the San Joaquin River where canals, which now serve large irrigated areas in the lower San Joaquin Valley, head. A third plan considered involved an exchange of supplies from one stream to another, on the eastern side of the valley from the Feather River to Kern River. All of these plans would divert water above riparian owners and appropriative diversions in the Sacramento Valley. A fourth plan studied was a direct pumping system from the delta channels of the Sacramento and San Joaquin rivers to the upper San Joaquin Valley, without exchange of supplies. A fifth plan studied and adopted for this report provides for the diversion of the supplemental water supply by pumping from the Sacramento-San Joaquin Delta and an exchange of supplies on the San Joaquin River. A summarized comparison of these plans, together with estimates of capital and annual costs for a conveyance capacity of 3000 second-feet, are presented in Chapter VIII in the discussion of the plan for complete initial development.

The adopted plan of conveyance includes a pumping system on the San Joaquin River to transport water from Sacramento-San Joaquin Delta to Mendota. It provides for the exchange of a portion of the pumped water for San Joaquin River water which would be diverted at the Friant Reservoir, 61 miles farther upstream and 308 feet higher in elevation than the point of delivery of imported water at Mendota. It provides conduits leading north and south from Friant Reservoir to convey San Joaquin River water to the lands on the eastern slope of the upper San Joaquin Valley. An extension of the pumping system southerly from Mendota is provided to serve the lands on the western slope of the upper San Joaquin Valley. The advantages of the plan are many. Both capital and annual costs would be much less than for conveyance by any other method. By means of the proposed exchange at Mendota, a pumping lift of about 300 feet would be saved over a direct pumping plan. Diversion in the Sacramento-San Joaquin Delta would be effected below all the riparian lands in the Sacramento River Basin. The source of the water supply in the Sacramento-San Joaquin Delta is the temporary catch-basin of the run-off and return water from 42,900 square miles of drainage area, which comprises 74 per cent of the entire area of the Sacramento and San Joaquin River basins and contributes 91 per cent of the run-off of the two basins. Water developed in any part of the two basins north of the upper San Joaquin River would naturally find its way to this catch-basin. The flexibility of the plan would be of great advantage. It would lend itself more readily to progressive development with minimum expenditures and it would interfere least with present rights and interests. By this plan, full recharge of ground water storage would be made by gravity diversion from Friant, whereas any other plan not providing for exchange of water at Mendota would require a greatly increased pumping lift for such purpose. These great advantages would not be attained by any scheme that does not utilize the delta as a source of supply, and only in part, if not combined with exchange with San Joaquin River water.

The conveyance units, natural and constructed, which would be required for the exportation and delivery of water from the Sacramento River Basin to the lands of the San Joaquin River Basin would extend from the Sacramento River at the head of Snodgrass Slough to the southern extremity of the San Joaquin Valley. These major conveyance units and their principal physical features are set forth in Table 102. Their locations are indicated in outline on Plate XXVI.

TABLE 102

MAJOR CONVEYANCE UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Maximum capacity, in second-feet	Length, in miles	Number of pumping plants	Elevation of diversion, in feet*	Elevation of terminus, in feet*	Pumping lift, in feet	
						Maximum	Average weighted
Sacramento-San Joaquin Delta Cross Channel	10,000	24	0	3±	1±	0	0
San Joaquin River Pumping System	8,000	167	10	0	159	202	185
San Joaquin River-Kern County Canal	3,000	165	0	467	358	0	0
Madera Canal	1,500	18	0	415	391	0	0
Kern River Canal	1,500	75	0	680	591	0	0
Mendota West Side Pumping System	4,500	100	6	159	250	150	117
Totals		549	16				

* U. S. Geological Survey datum.

In making studies of the conveyance units of the adopted plan and also of the various alternates, full use was made of all available maps and surveys. Preliminary locations of all conveyance channels were made first on U. S. Geological Survey topographic maps. It was desirable and necessary, however, to make additional surveys in many instances. This was done particularly for the units which are of more immediate importance.

In studying the locations of the Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System, topographic surveys were made of channels from Hood to New Hope in the delta. Existing U. S. Engineer Department maps of the delta and San Joaquin River channels and levees, all on a scale of one inch equals 400 feet, were revised to date by a plane table survey from New Hope to Mendota, a distance of about 200 miles. Additional maps also were made of Fresno Slough for 10 miles south of Mendota. These surveys cover an area of about 130,000 acres.

Two locations were investigated for the San Joaquin River-Kern County Canal. The first location involved an exchange of supplies at Kings River. It would have diverted from Friant Dam at an elevation of 420 feet and discharged into the Kings River about two miles south of Sanger at elevation 325. The second location studied and adopted has a diversion elevation at Friant Dam of 467 feet and crosses the Kings River without exchange of supplies at elevation 445 feet. From Kings River south the same location was used for both plans. In studying these plans, two field locations with profiles and supplemental topographic surveys were made between Friant dam site and Kings River, each traversing a distance of about 35 miles. A field location was made and a profile secured from Kings River south to Kern Island Canal a distance of 132 miles. Special topographic surveys were made of river, canal, road and railroad crossings and of all parts of the location in irregular topography and other points where more detailed information was desired, and mapped on a large scale for location studies.

The Madera Canal was located on U. S. Geological Survey topographic maps and the location compared with a location plotted on topographic surveys, scale one inch equals 200 feet, made by the Madera Irrigation District for a canal traversing practically the same route.

A preliminary field location was made of the Kern River Canal from the point of diversion southward and around the head of the valley for a distance of about 40 miles. The total length of this canal location is 75 miles. The last 35 miles on flat smooth topography were located partly on U. S. Geological Survey topographic maps and partly on topographic maps made by private agencies. A special topographic survey for preparing a large scale map was made of the first seven miles where more detailed information was required for determining the most economical combination of canal and tunnel location along the south side of Kern River and under the mesa about eight miles east of Bakersfield.

The location of the Mendota-West Side Pumping System was made entirely on U. S. Geological Survey topographic maps aided by field examinations. These maps have a scale of two inches equals one mile and a five-foot contour interval. The topography traversed by the location is relatively flat and smooth.

Estimates of cost for the conveyance units are presented under the following discussions of each unit. The unit prices of construction set forth herein are for the items in place and are exclusive of amounts for administration, engineering, contingencies and interest during construction. To each cost estimate there has been added 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction at 4.5 per cent, computed on a basis of financing at the beginning of each six months and compounded to the end of the construction period.

Annual costs, including interest and amortization on bonds, depreciation, and operation and maintenance, were estimated for each unit. Annual electric energy costs were estimated for conveyance units having pumping plants. The bases for estimating the annual costs are as follows:

Item	*Annual cost, in per cent of capital cost*
Interest	4.5
Amortization of capital investment (40-year sinking fund basis at 4 per cent)	1.05
Depreciation:	
Canals	0.65
Minor concrete structures	0.35
Tunnels	0.35
Pumping plants—	
Concrete buildings and structures	0.35
Electrical and mechanical equipment	2.40
Steel leaf dams	1.05
Operating expenses and maintenance:	
Canals	2.30
Minor concrete structures	1.60
Tunnels	1.60
Canal right of ways	0.45
Pumping Plants—	
Concrete buildings and structures	1.60
Electrical and mechanical equipment	5.55
Steel leaf dams	3.90

Electric energy charges for pumping are in accord with the power schedules of the public utilities distributing power in the regions in which the pumping plants are located.

A description, types of conveyance channels and appurtenances, considerations governing location, other pertinent physical data and estimates of capital and annual costs are set forth for each major conveyance unit in the following presentation.

Sacramento-San Joaquin Delta Cross Channel.

The most northerly unit of the conveyance system, the Sacramento-San Joaquin Delta Cross Channel, is designed to carry from the Sacramento River to the San Joaquin River Delta the water required to meet the four-fold demand of salinity control, delta consumptive use, agricultural and industrial uses in Contra Costa County and exportation to the San Joaquin Valley. The present channel capacity provided by the two interconnecting channels of Georgiana and Three Mile sloughs is hardly sufficient to take care of the consumptive demands in the San Joaquin Delta, if all or most of the water supply required were to come from the Sacramento River. Approximately two-thirds of the irrigable area of the Sacramento-San Joaquin Delta is in the San Joaquin portion thereof. The net stream flow past Antioch required for the prevention of saline invasion into the delta, under the proposed plan of salinity control*, must be distributed in both the Sacramento and San Joaquin river channels, in proportion to the magnitude of tidal diffusion therein. Therefore, it is necessary to provide additional channel capacity from the Sacramento River to the San Joaquin Delta, of such magnitude that complete flexibility in

*Bulletin No. 27, "Variation and Control of Salinity in Sacramento–San Joaquin Delta and Upper San Francisco Bay, Division of Water Resources, 1931."

the distribution of the inflow would be available to allow the water to flow automatically to the portions of the basin where needed to satisfy the consumptive demands and demands of salinity control in the delta and transfer surplus water from the Sacramento River through the San Joaquin Delta channels to the lower end of the San Joaquin River pumping system.

Under present conditions, most of the flow of the Sacramento River into the San Joaquin Delta goes through Georgiana Slough. This slough diverts from the Sacramento River just below Walnut Grove and connects with the Mokelumne River about 3½ miles above its junction with the San Joaquin River. It is a tidal channel and the flow is nonuniform and fluctuates with the rise and fall of the tide. However, except for conditions of relatively low flow in the Sacramento River when there is an occasional reversal of flow of short duration from the San Joaquin River into the Sacramento River, the flow although varying in rate is predominantly from the Sacramento River to the San Joaquin River. Based upon the measurements in 1929, the flow through Georgiana Slough in per cent of the flow in the Sacramento River passing Sacramento is as follows:

Flow in Sacramento River passing Sacramento in second-feet	*Flow through Georgiana Slough in per cent of flow passing Sacramento*
3,000	43½
5,000	36
10,000	24
20,000	17½
40,000 to 60,000	15

Continuous records of tidal stage at each end of Georgiana Slough show that the mean tidal elevation at the Walnut Grove end is higher than the mean tidal elevation at the lower Mokelumne River end.

The flow through Three Mile Slough, as shown by detailed measurements in 1929, is extremely variable. There is a complete reversal of flow through the channel between the Sacramento and San Joaquin rivers with each successive flood and ebb tide, regardless of the flow in the Sacramento River up to flows of 100,000 second-feet passing Sacramento. Over a considerable period of time, the measurements show that there is a net transfer of water from the Sacramento to the San Joaquin River. However, it is small in amount and hence Three Mile Slough is of small importance as a means of transferring water from the Sacramento River to the San Joaquin Delta.

With the regulated flows which would be required in the Sacramento River for ultimate development, the flow through Georgiana Slough into the San Joaquin Delta would provide only a part of the water required to meet the fourfold demand previously stated. The flow through Georgiana Slough would be only 2000 to 3000 second-feet whereas the flow required into the San Joaquin Delta to meet the fourfold demand previously stated would amount in the maximum month of demand to about 12,000 second-feet for ultimate development. The additional channel capacity required for ultimate development would, therefore, amount to about 9000 to 10,000 second-feet. Studies have been made to determine the most practicable plan of obtaining the required additional connecting channel capacity. A consideration of possible locations for a new connecting channel showed that the most practicable route would be through Snodgrass Slough and the Mokelumne River Channels. Snodgrass Slough heads below Hood near the east bank of the Sacramento River about ten miles above Walnut Grove and joins the Mokelumne River at Dead Horse Island near New Hope Landing. At New Hope Landing, the Mokelumne River divides into two channels, the North and South forks, which subsequently join near the junction of the Mokelumne River and Georgiana Slough, about two miles upstream from the junction of the Mokelumne and San Joaquin rivers at Central Landing. Other sloughs, the principal of which are Potato and Little Connection, connect the South Fork of the Mokelumne River directly with the San Joaquin River.

Plans for Development Investigated—Two plans of development were considered. The first plan provides for the utilization of Georgiana Slough with an additional channel cut from the head of this slough to Snodgrass Slough at the westerly end of Dead Horse Island; and, in addition, a new connecting channel cut through from the Sacramento River to the head of Snodgrass Slough which would be enlarged to its junction with the Mokelumne River. No diversion dam would be provided in the Sacramento River and the channels would be designed to obtain the required capacity under conditions of tidal fluctuation. The second plan of development considered provides for a similar new connecting channel along the route of Snodgrass Slough with the diversions into and through this new channel controlled by a dam across the Sacramento River and gates at the head of the new cut leading into Snodgrass Slough.

Under the first plan considered, a channel with a bottom width of about 325 feet from the upper end of Snodgrass Slough to Dead Horse Island would be required. In addition extensive enlargement would be necessary in the upper end of the South Fork of the Mokelumne River. A headgate at the intake of Snodgrass Slough having practically the same area of opening as the cross-sectional area of the Sacramento River opposite its head would be required. Draw or bascule highway bridges would be required at New Hope Landing on the South Fork and near the junction with Snodgrass Slough on the North Fork of the Mokelumne River. A new draw or bascule bridge also would be required for the Southern Pacific railroad crossing over Snodgrass Slough. The new channel cut from the head of Georgiana Slough to Snodgrass Slough would require a gate structure at its head, and, in addition, an embankment about 2000 feet in length and a bridge crossing for the Southern Pacific Railroad.

The second plan, although requiring a dam across the Sacramento River which would be equipped with locks to accommodate navigation, would require a channel along Snodgrass Slough of only about 125 feet in bottom width. Channel excavation and enlargement would be but a small percentage of that required in the first plan. No new bascule or draw bridges for either highway or railroad crossings would be required. The headgate structure at the head of the new channel would require a much smaller opening and involve a smaller cost than under the first plan. This plan would not include a new channel cut from the head of Georgiana Slough to Snodgrass Slough as provided in the first plan.

The second plan would appear to have advantages over the first plan. In the first place, the estimated cost of the second plan is less than that for the first. Secondly, the second plan would be more positive in operation and accomplishment. Thirdly, although the necessity for lockage would be of some disadvantage by delays to navigation, it would have the advantage of affording slack water navigation above the dam to Sacramento. Therefore, it is believed that the second plan involving a controlled channel would be the more advantageous plan of development for adoption.

Cost of Sacramento-San Joaquin Delta Cross Channel—In the light of the investigations and studies which have been made thus far, the plan of controlled channel development for the Sacramento-San Joaquin Delta Cross Channel has been adopted tentatively as a basis for estimating the cost of this unit. Table 103 sets forth the estimate of cost, including the capital costs of the channel and all appurtenant works, right of ways and spoil areas, and the total annual cost. The cost of the control works on the Sacramento River is based on the cost of a dam and lock as estimated by the U. S. Army Engineers and set forth on pages 74 and 75 in House of Representatives Document No. 123, Sixty-ninth Congress, first session.

TABLE 103

COST OF SACRAMENTO-SAN JOAQUIN DELTA CROSS CHANNEL

Control works on Sacramento River	$2,300,000
Headgate structure at head of Snodgrass Slough for channel 125 feet wide	150,000
2 secondary road bridges over Snodgrass Slough	126,000
Minor structures and protective works	100,000
Excavation, enlarging Snodgrass Slough and upper end of North and South Forks of Mokelumne River, 2,000,000 cubic yards at $0.10	200,000
Right of way and spoil areas	150,000
Subtotal	$3,026,000
Administration and engineering, at 10 per cent	303,000
Contingencies, at 15 per cent	454,000
Interest during construction, based on an interest rate of 4½ per cent per annum	217,000
Total capital cost	$4,000,000
Total annual cost	$300,000

San Joaquin River Pumping System.

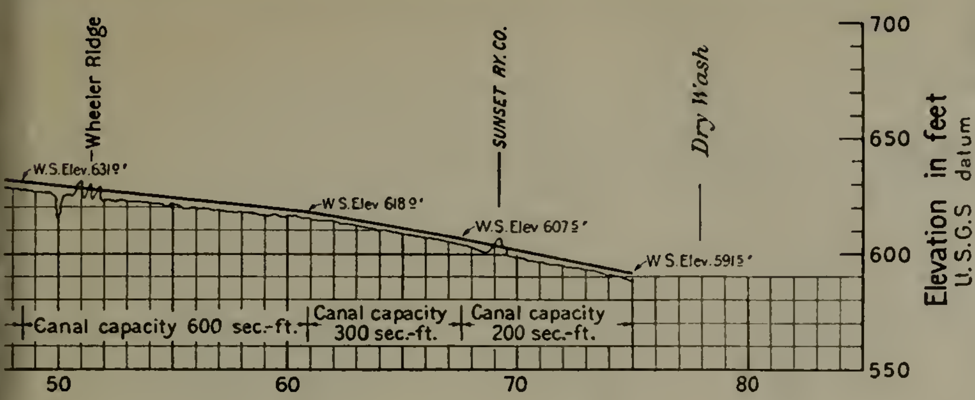
From Central Landing at the lower end of the Sacramento-San Joaquin Delta Cross Channel to the first unit of the San Joaquin River Pumping System below Mossdale Bridge, the conveyance system would comprise chiefly three existing channels, each about 30 miles in length. The most easterly of these channels would be the Stockton Deep Water Channel and the San Joaquin River. The other two channels would be Old River and Salmon Slough, and Middle River with artificial connections already constructed such as the Victoria-North Canal and the Grant Line Canal. With some enlargement in portions of these channels, the conveyance capacity is adequate to meet the requirements for exportation to the San Joaquin River Basin and also for delta irrigation use.

Many different plans were considered for a pumping system to convey water from the delta to Mendota. These varied in range from that of a plan to attain the total elevation required by a series of pumping lifts located on the shortest line possible from a point near Paradise Dam westerly toward the foothills and thence continuing southerly through a constructed gravity canal along the west slope of the valley to Mendota, to a plan with a series of dams and pumping lifts utilizing the channel of the San Joaquin River throughout its entire length from the delta to Mendota. Several of the more feasible of the alternate plans investigated are presented in Chapter VIII for a 3000 second-feet capacity plan for complete initial development. The plan adopted for this unit of the proposed conveyance system for ultimate development is the one which, in the light of the studies and investigations made thus far, seems to present the greatest advantages from all viewpoints.

The first unit of the proposed San Joaquin River Pumping System is located just above the point of bifurcation of the San Joaquin River and Old River. From this point to the mouth of the Merced River, the channel of the San Joaquin River would be utilized for a distance of 72 miles. By means of a series of five successive dams and pumping plants, water would be conveyed from the delta and raised to an elevation of 62 feet, U. S. Geological Survey datum. The dams used for this portion of the pumping system are of the collapsible type providing an unobstructed channel to permit free discharge in case of large flows. The maximum capacity of the pumping system would be 8000 second-feet.

From the pond above Plant No. 5, it is proposed to depart westerly from the river with a constructed canal extending southerly along the most favorable topography. By means of three pumping lifts in a distance of seven miles, the water would be raised to an elevation of 137 feet at the discharge of Plant No. 8 and would continue a distance of sixteen miles to Plants No. 9 and No. 10, about five miles west of Los Banos. A portion of the pumped water would be diverted into existing canal systems serving lands lying below Plant No. 9. From the discharge of Plant No. 10, at an elevation of 180 feet, the canal would extend southerly about 38 miles to the Mendota Weir, delivering water at an elevation of 159 feet. The pond above the Mendota Weir would be the source of supply for lands now served by diversions at and near this point. Local pumping projects would be required for serving west side rim lands above present developed areas. The total distance from Pumping Plant No. 1 to Mendota Weir would be 135 miles. The location and profile of the San Joaquin River Pumping System are shown respectively on Plate XXVI and on Plate LVII, "Profile of Major Conveyance Units of State Plan for Ultimate Development in San Joaquin Valley, Sacramento-San Joaquin Delta to Kern County." Plans of typical pumping plants and a collapsible steel leaf dam are shown on Plate LVIII, "Typical Designs, Dam and Pumping Plants for San Joaquin River Pumping System."

The height of each pumping lift and the capacity of each pumping plant are set forth in Table 104. The average seasonal amount of water that would have been pumped through each lift and the estimated average seasonal energy consumption for the 12-year period 1917–1929 also are given in the tabulation. In arriving at these values, credit was allowed for return flows from the Merced, Tuolumne and Stanislaus rivers for conditions of ultimate irrigation and municipal development. The probable return flows above each dam were estimated very conservatively to insure an energy consumption estimate that would provide for repumping possible seepage losses between lifts.



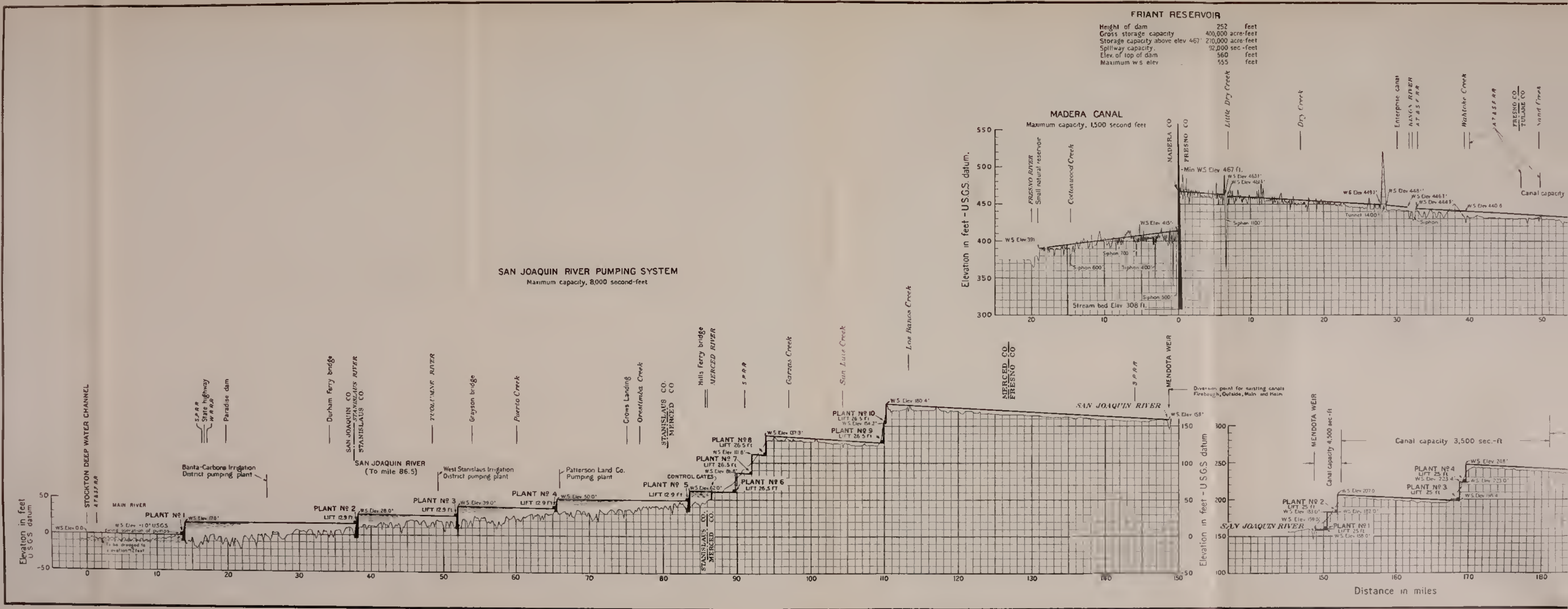
PROFILE OF

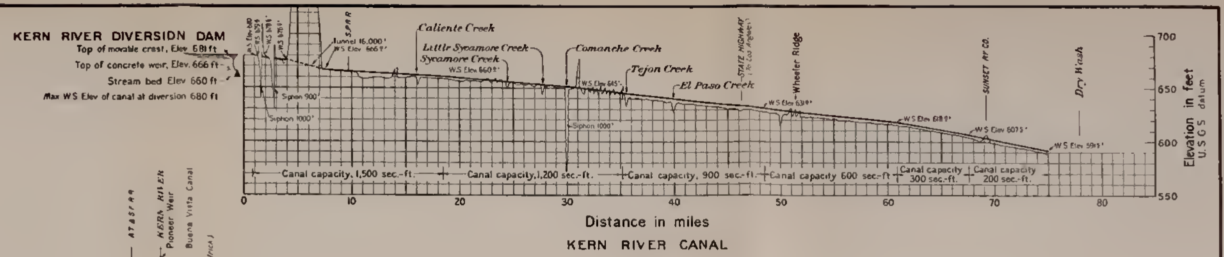
ANCE UNITS OF STATE PLAN

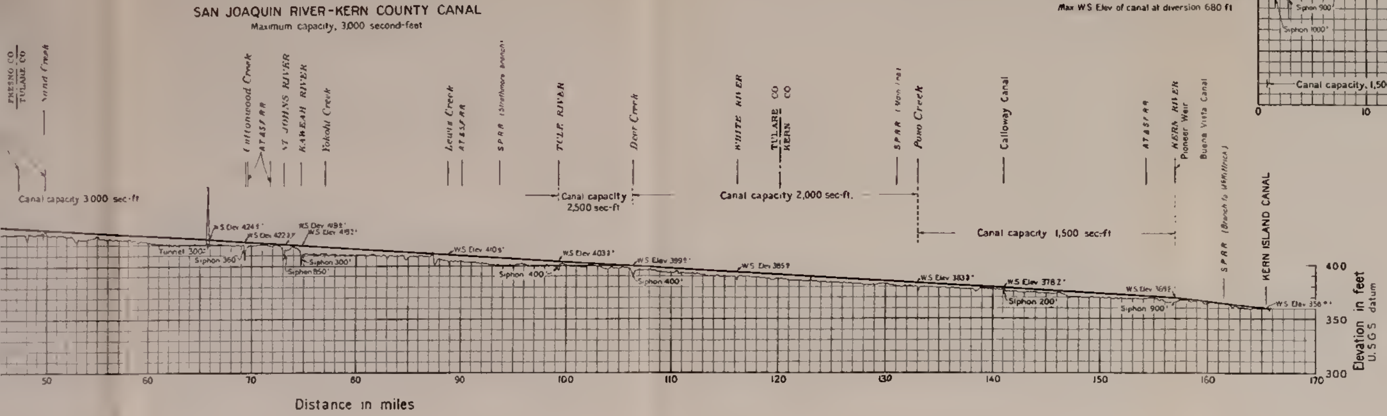
TIMATE DEVELOPMENT

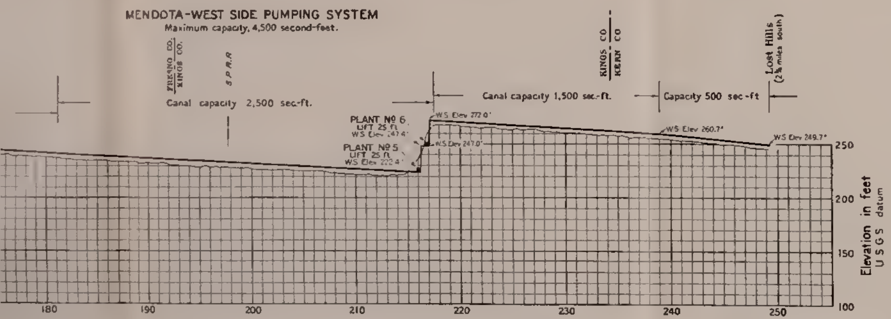
AN JOAQUIN VALLEY

I-SAN JOAQUIN DELTA TO KERN COUNTY


FRIANT RESERVOIR
Height of dam 252 feet
Gross storage capacity 400,000 acre-feet
Storage capacity above elev 467' 270,000 acre-feet
Spillway capacity 92,000 sec.-feet
Elev. of top of dam 560 feet
Maximum W.S. elev 555 feet
MADERA CANAL
Maximum capacity, 1,500 second feet
SAN JOAQUIN RIVER PUMPING SYSTEM
Maximum capacity, 8,000 second-feet
Elevation in feet - U.S.G.S. datum
Elevation in feet U.S.G.S. datum
STOCKTON DEEP WATER CHANNEL
MAIN RIVER
PLANT Nº 1
PLANT Nº 2
PLANT Nº 3
PLANT Nº 4
PLANT Nº 5
PLANT Nº 6
PLANT Nº 7
PLANT Nº 8
PLANT Nº 9
PLANT Nº 10
Banta-Carbona Irrigation District pumping plant
SAN JOAQUIN RIVER (To mile 86.5)
West Stanislaus Irrigation District pumping plant
Patterson Land Co. Pumping plant
CONTROL GATES
Durham Ferry bridge
TUOLUMNE RIVER
Grayson bridge
Puerto Creek
Crows Landing
Orestimba Creek
Hills Ferry bridge
MERCED RIVER
Garzas Creek
San Luis Creek
Los Banos Creek
MENDOTA WEIR
SAN JOAQUIN RIVER
Diversion point for existing canals Firebaugh, Outside, Main and Helm
Canal capacity 3,500 sec.-ft
Distance in miles







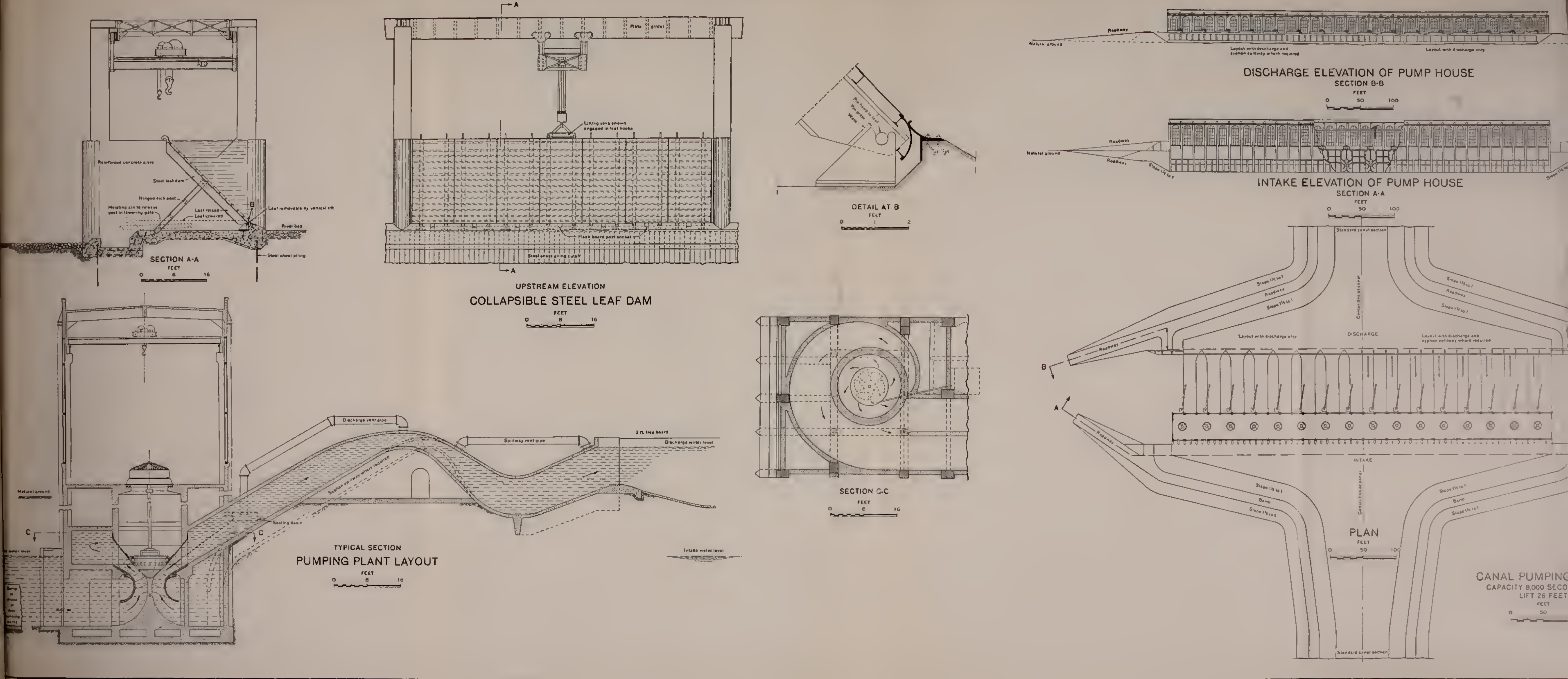
PROFILE OF

MAJOR CONVEYANCE UNITS OF STATE PLAN

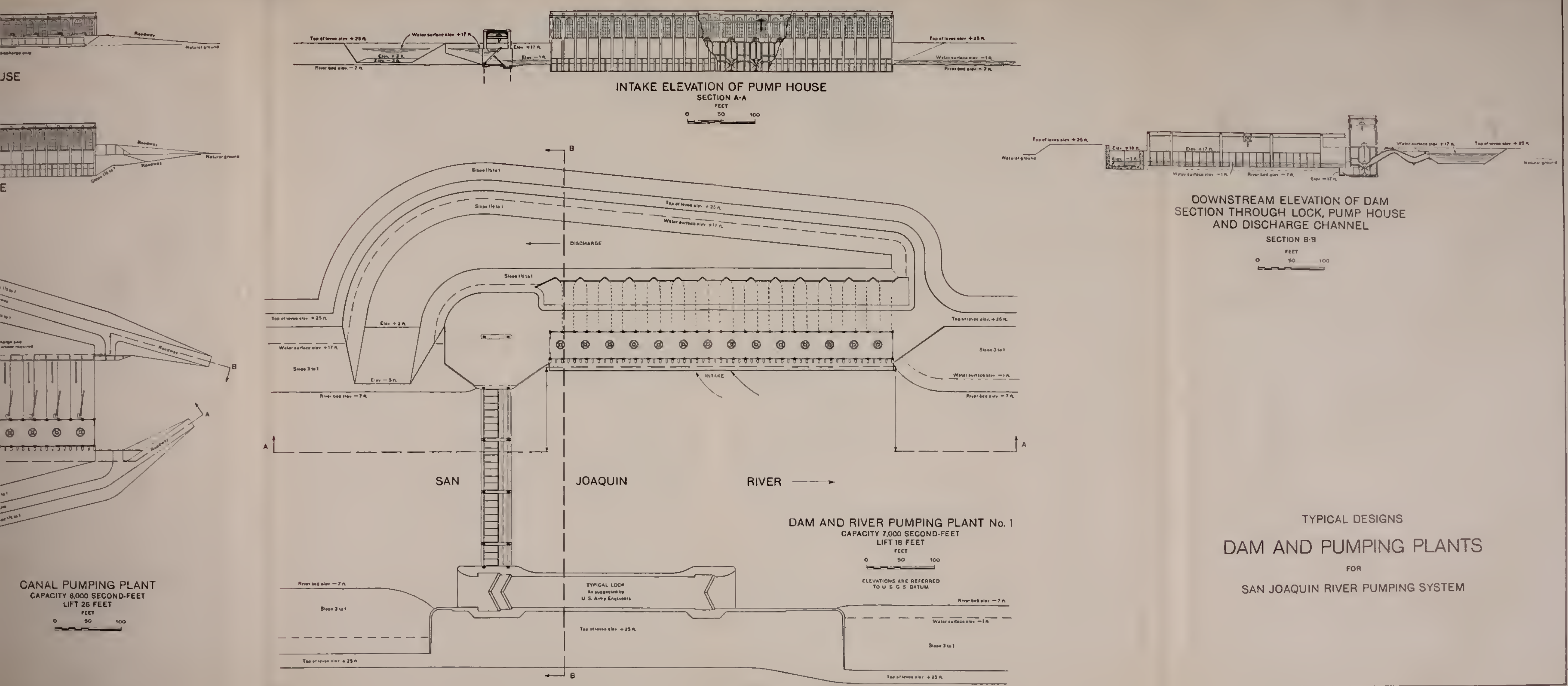
FOR ULTIMATE DEVELOPMENT

IN SAN JOAQUIN VALLEY

SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY



SECTION A-A
FEET
0 8 16
Reinforced concrete piers
Steel leaf dam
Hinged kick post
Hoisting pin to release post in lowering gate
Leaf raised
Leaf lowered
Leaf removable by vertical lift
River bed
Steel sheet piling
Plate girder
Lifting yoke shown engaged in leaf hooks
Flash board post socket
Steel sheet piling cutoff
UPSTREAM ELEVATION
COLLAPSIBLE STEEL LEAF DAM
FEET
0 8 16
DETAIL AT B
FEET
0 1 2
DISCHARGE ELEVATION OF PUMP HOUSE
SECTION B-B
FEET
0 50 100
Roadway
Natural ground
Layout with discharge and syphon spillway where required
Layout with discharge only
INTAKE ELEVATION OF PUMP HOUSE
SECTION A-A
FEET
0 50 100
Standard canal section
Slope 1½ to 1
Roadway
Centerline of canal
DISCHARGE
Layout with discharge only
Layout with discharge and syphon spillway where required
INTAKE
Berm
PLAN
FEET
0 50 100
Discharge vent pipe
Spillway vent pipe
2 ft. free board
Discharge water level
Natural ground
Syphon spillway where required
Sealing basin
Intake water level
TYPICAL SECTION
PUMPING PLANT LAYOUT
FEET
0 8 16
SECTION C-C
FEET
0 8 16
CANAL PUMPING
CAPACITY 8,000 SECO
LIFT 26 FEET
FEET
0 50



TYPICAL DESIGNS

DAM AND PUMPING PLANTS

FOR

SAN JOAQUIN RIVER PUMPING SYSTEM

TABLE 104

PUMPING LIFTS AND CAPACITIES, SEASONAL QUANTITY OF WATER PUMPED AND SEASONAL ENERGY CONSUMPTION FOR SAN JOAQUIN RIVER PUMPING SYSTEM

Location and number of pumping plant	Height of lift, in feet	Capacity of plant, in second-feet	Seasonal quantity of water pumped, in acre-feet[1]	Seasonal energy consumption, in kilowatt hours[1]
At Dams on San Joaquin River—				
1	18.0	7,000	1,828,000	56,184,000
2	12.9	7,000	1,845,000	40,639,000
3	12.9	7,500	2,158,000	47,534,000
4	12.9	7,500	2,158,000	47,534,000
5	12.9	7,500	2,124,000	46,785,000
First Group of Canal Lifts near Newman—				
6	26.5	8,000	2,438,000	110,316,000
7	26.5	8,000	2,438,000	110,316,000
8	26.5	8,000	2,438,000	110,316,000
Second Group of Canal Lifts near Los Banos				
9	26.5	6,500	2,225,000	100,679,000
10	26.5	6,500	2,225,000	100,679,000
Totals	202.1			770,982,000
Average weighted lift	185.0			

[1] Average for 12-year period 1917-1929.

PLATE LIX

MENDOTA WEIR ON SAN JOAQUIN RIVER

Cost of San Joaquin River Pumping System—An estimate of cost based on unit prices set forth in Table 105 is presented in Table 106. The estimate sets forth the capital cost of the complete pumping system including conveyance channels, pumping plants, steel leaf dams, minor structures, right of ways and spoil areas. The total annual cost, including the average annual charge for electric energy, also is given in the tabulation.

TABLE 105

UNIT PRICES USED IN COST ESTIMATE OF SAN JOAQUIN RIVER PUMPING SYSTEM

Excavation and embankment—	
River channel excavation	$0.10 per cu. yd.
Levee embankment	.15 per cu. yd.
Canal excavation in earth:	
First 13 feet in depth	.18 per cu. yd.
13 to 18 feet in depth	.22 per cu. yd.
18 to 23 feet in depth	.25 per cu. yd.
23 to 28 feet in depth	.28 per cu. yd.
28 to 33 feet in depth	.32 per cu. yd.
Canal excavation in hardpan	.60 per cu. yd.
Canal embankment in earth (10 per cent shrinkage allowance):	
First 8 feet of fill	.18 per cu. yd.
8 to 13 feet of fill	.20 per cu. yd.
Concrete—	
Reinforced concrete canal lining, 3¼ inches thick, based on concrete at $10.00 per cubic yard and steel at $0.06 per pound in place	$0.15 per sq. ft.
Concrete in dams and pumping plants, exclusive of reinforcing	17.00 per cu. yd.
Reinforcing steel	.06 per lb.
Concrete in bridges and minor structures, exclusive of reinforcing	15.00 per cu. yd.
Reinforcing steel	.06 per lb.
Steel leaf dams—	
Excavation—20 cu. yds. at $0.30 and 7 cu. yds. at $6.00	$48.00 per lin. ft. of dam
Steel sheet piling—3,100 lbs. at $0.06	186.00 per lin. ft. of dam
Concrete, exclusive of reinforcing—	
7 cu. yds. at $17.00	119.00 per lin. ft. of dam
Reinforcing steel—500 lbs. at $0.06	30.00 per lin. ft. of dam
Gate steel—leaf and struts—1,250 lbs. at $0.10	125.00 per lin. ft. of dam
Superstructure steel—bridge and bracing—650 lbs. at $0.10	65.00 per lin. ft. of dam
Traveling crane, total cost $10,000. Average	40.00 per lin. ft. of dam
Total	$613.00 per lin. ft. of dam
Pumping Plants—	
For a lift of 13 feet:	
Excavation	$4,000 per 500 sec. ft. unit
Concrete sump, building, pump shell, discharge and spillway	31,500 per 500 sec. ft. unit
Pump and metal liner in pump shell	5,100 per 500 sec. ft. unit
Synchronous motor	6,200 per 500 sec. ft. unit
Transformer	4,750 per 500 sec. ft. unit
Exciters, switches and other electrical equipment	1,600 per 500 sec. ft. unit
Total	$53,150 per 500 sec. ft. unit
For a lift of 18 feet:	
Excavation	$4,000 per 500 sec. ft. unit
Concrete sump, building, pump shell, discharge and spillway	34,000 per 500 sec. ft. unit
Pump and metal liner in pump shell	6,000 per 500 sec. ft. unit
Synchronous motor	7,250 per 500 sec. ft. unit
Transformer	5,600 per 500 sec. ft. unit
Exciters, switches and other electrical equipment	1,900 per 500 sec. ft. unit
Total	$58,750 per 500 sec. ft. unit
For a lift of 26.5 feet:	
Excavation	$4,000 per 500 sec. ft. unit
Concrete sump, building, pump shell, discharge and spillway	38,000 per 500 sec. ft. unit
Pump and metal liner in pump shell	7,500 per 500 sec. ft. unit
Synchronous motor	9,000 per 500 sec. ft. unit
Transformer	7,000 per 500 sec. ft. unit
Exciters, switches and other electrical equipment	2,500 per 500 sec. ft. unit
Total	$68,000 per 500 sec. ft. unit

TABLE 106

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM

Central Landing to Hills Ferry—		
Length, 102 miles. Capacity, varies from 7,000 to 7,500 second-feet.		
Excavation and embankment:		
Enlargement of delta channels below Dam No. 1, 8,000,000 cubic yards at $0.10	$800,000	
Channel changes and enlargement between dams, 4,000,000 cubic yards at $0.10	400,000	
Levee embankments above dams, 600,000 cubic yards at $0.15	90,000	
Pumping plants:		
Lift No. 1, capacity 7,000 second-feet	823,000	
Lift No. 2, capacity 7,000 second-feet	744,000	
Lift No. 3, capacity 7,500 second-feet	796,000	
Lift No. 4, capacity 7,500 second-feet	797,000	
Lift No. 5, capacity 7,500 second-feet	796,000	
Steel leaf dams:		
Dam No. 1	172,000	
Dam No. 2	172,000	
Dam No. 3	123,000	
Dam No. 4	208,000	
Dam No. 5	147,000	
Minor structures:		
Drainage culverts through levees	20,000	
Control works at Paradise Dam	25,000	
Maintaining existing bridges during construction	50,000	
Right of ways:		
Delta channel enlargement and spoil areas	150,000	
River levees and spoil areas	120,000	
		$6,433,000
Hills Ferry to Mendota—		
Length, 63 miles. Capacity, varies from 8,000 to 6,500 second-feet.		
Excavation:		
Canals in deep cut and fill sections near pumping plants, 3,200,000 cubic yards at $0.20 to $0.23	$713,000	
Canals with regular concrete lined section:		
Earth, 7,388,000 cubic yards at $0.18	1,330,000	
Hardpan, 213,000 cubic yards at $0.60	128,000	
Spillway channel near Los Banos:		
Earth, 278,000 cubic yards at $0.18	50,000	
Reinforced concrete canal lining:		
37,895,000 square feet at $0.15	5,684,000	
Pumping plants:		
Lift No. 6, capacity 8,000 second-feet	1,088,000	
Lift No. 7, capacity 8,000 second-feet	1,088,000	
Lift No. 8, capacity 8,000 second-feet	1,088,000	
Lift No. 9, capacity 6,500 second-feet	884,000	
Lift No. 10, capacity 6,500 second-feet	884,000	
Minor structures on portion of canal having a capacity of 8,000 second-feet:		
Intake gates in cut near Hills Ferry	60,000	
Siphons, 3 at $30,000	90,000	
Railroad crossing	50,000	
Road bridges, 20 at $12,000	240,000	
Spillway channel control	30,000	
Bridges on spillway channel, 3 at $8,000	24,000	
Outlets, 2 at $5,000	10,000	
Underdrains, 3 at $4,000	12,000	
Minor structures on portion of canal having a capacity of 6,500 second-feet:		
Road bridges, 18 at $10,000	180,000	
Siphon	25,000	
Railroad crossing	40,000	
Outlets, 2 at $5,000	10,000	
Underdrains, 5 at $3,000	15,000	
Right of ways and fencing	444,000	
		14,167,000
Subtotal		$20,600,000
Administration and engineering, at 10 per cent		2,060,000
Contingencies, at 15 per cent		3,090,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		2,750,000
Total capital cost		$28,500,000
Annual cost, exclusive of energy		$2,539,000
Average annual energy charge, 770,982,000 kilowatt hours at $0.0055		4,240,000
Total annual cost		$6,779,000

San Joaquin River-Kern County Canal.

The San Joaquin River-Kern County Canal is proposed for the conveyance of San Joaquin River water for use on the eastern slope of the upper San Joaquin Valley south of San Joaquin River. It extends from Friant Reservoir southward along the eastern rim of the valley a distance of 165 miles to a point about five miles south of

Bakersfield. The location of this canal is shown on Plate XXVI and its profile on Plate LVII.

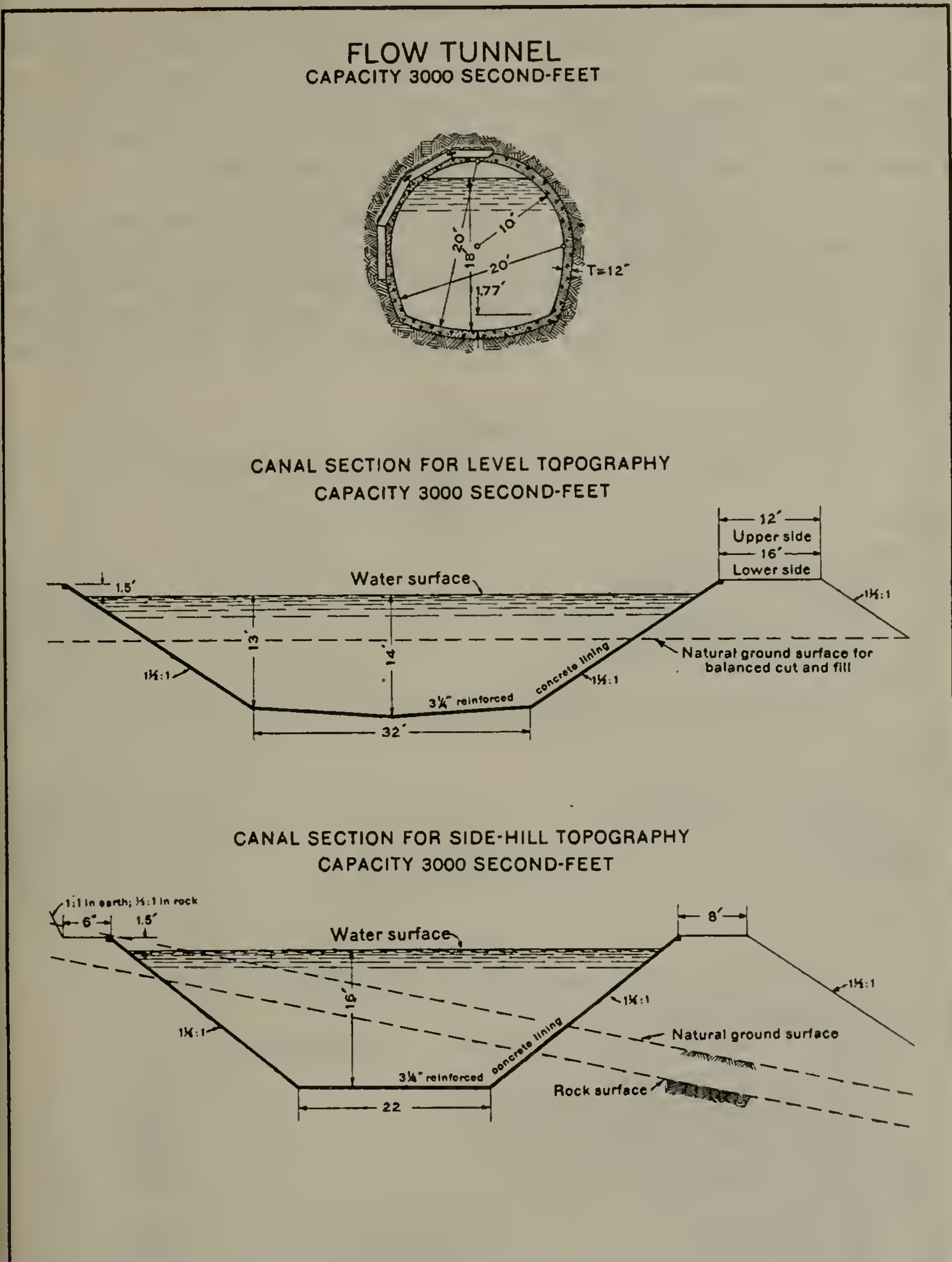
From the outlet at Friant Dam, at elevation 467 feet, the canal extends in a general southeasterly direction over the rough foothill topography lying between the San Joaquin and Kings River, a distance of 32 miles. Along this section the channels of Little Dry Creek and Dry Creek would be crossed by means of inverted siphons. An inverted siphon is provided for the crossing of Kings River, with a water surface elevation of 446 feet at the intake. Leaving the outlet of the Kings River siphon crossing with a water surface elevation of 445 feet, the canal extends in a direction somewhat more southerly and follows the toe of the mountain slopes for 55 miles to the town of Lindsay. Along this stretch the St. Johns and Kaweah rivers are crossed in reinforced concrete inverted siphons. At Lindsay, the canal turns due south and gradually swings with the trend of the topography of the valley floor to a direction somewhat west of south, continuing this general course for a distance of 50 miles to a point about four miles north of Shafter in Kern County. Between Lindsay and Shafter, the canal crosses the channels of Tule River, Deer Creek, White River and Poso Creek with inverted siphons. North of Shafter the alignment swings in a direction generally southeast and the canal extends an additional 19 miles to the siphon crossing of Kern River at elevation 369 feet, just upstream from the existing Pioneer Weir in Section 6, T. 30 S., R. 27 E., M. D. B. and M. Leaving the Kern River crossing, the canal continues an additional nine miles in a southeasterly direction gradually swinging to due east, intersecting the Buena Vista, Stine and Farmers canals en route and terminating at the Kern Island Canal, with a water surface elevation of 358 feet, in the northwest quarter of Section 30, T. 30 S., R. 28 E., five miles south of Bakersfield. The lengths, water surface elevations, grades, velocities and capacities of various sections of the San Joaquin River-Kern County Canal are set forth in Table 107. All portions of the canal in open conduit are concrete lined.

TABLE 107

PHYSICAL FEATURES AND HYDRAULIC ELEMENTS OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Point on canal location	Mile	Water surface elevation, in feet	Length of section, in miles	Grade in feet, per foot of length	Velocity of flow at full capacity, in feet per second	Capacity, in second-feet
Friant Dam	0	467				
			32.6	0.0001	4.6	3,000
Kings River	32.6	445				
			65.6	0.0001	4.4	3,000
Tule River	98.2	403				
			7.1	0.0001	4.2	2,500
Deer Creek	105.3	399				
			26.7	0.0001	4.0	2,000
Poso Creek	132.0	383				
			23.8	0.0001	3.7	1,500
Kern River	155.8	369				
			2.9	0.00015	3.9	1,000
Buena Vista Canal	158.7	367				
			5.8	0.00025	4.0	500
Kern Island Canal	164.5	358				

PLATE LX



TYPICAL CONDUIT SECTIONS
OF
SAN JOAQUIN VALLEY CONVEYANCE SYSTEMS

Plate LX, "Typical Conduit Sections of San Joaquin Valley Conveyance Systems," shows hydraulic properties and detail cross sections of the main types of conveyance channels used for a capacity of 3000 second-feet. Designs of typical structures for a canal of 3000 second-feet capacity are presented on Plate LXI, "River Syphon and Appurtenant Canal Structures"; Plate LXII, "Railroad Syphon"; Plate LXIII, "Highway Skew Bridge"; Plate LXIV, "Box Culvert Underdrain"; and Plate LXV, "County Road Bridge."

Cost of San Joaquin River-Kern County Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 109. The estimate sets forth the capital cost of the entire conduit and appurtenant structures, including canals, tunnels, siphons, bridges, other minor structures and right of ways. The total annual cost also is given.

TABLE 108

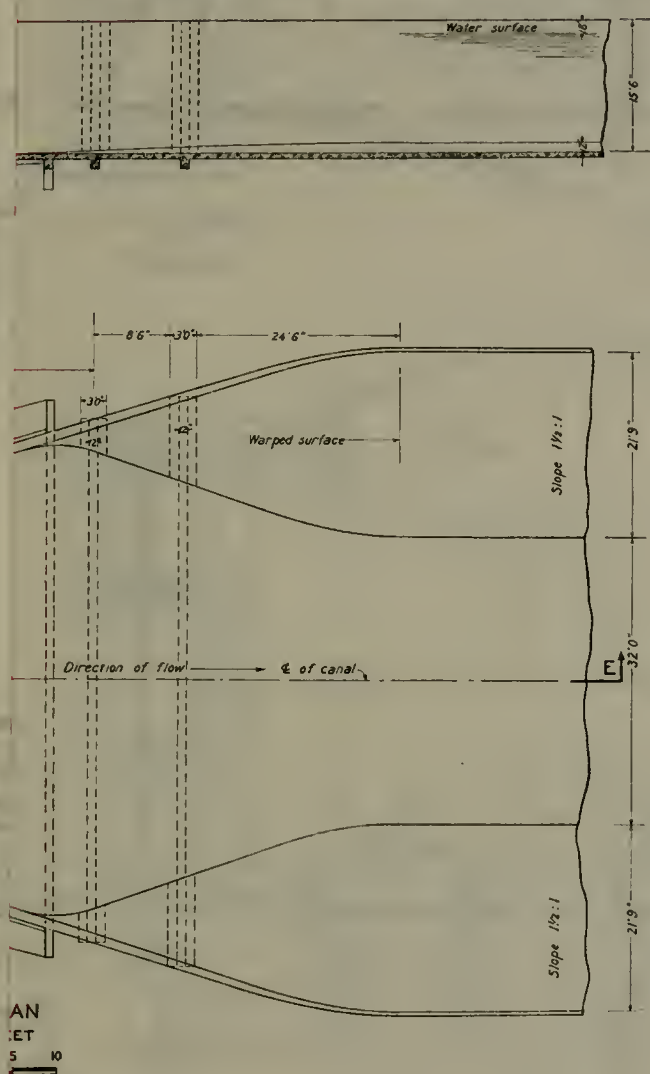
UNIT PRICES USED IN COST ESTIMATES OF SAN JOAQUIN VALLEY CONVEYANCE UNITS

Excavation—	
Canals:	
Rock, exclusive of trimming	$1.00 per cu. yd.
Trimming rock for concrete lining	.10 per sq. ft.
Hardpan	.60 per cu. yd.
Earth and cobble conglomerate	.60 per cu. yd.
Earth overlying rock excavation	.25 per cu. yd.
Earth, typical valley floor classification	.18 per cu. yd.
Tunnels:	
Section sufficiently large for mucking machines. Based on assumptions of ten per cent overbreak and a timbering requirement for 50 per cent of length	$9.00 per cu. yd.
Concrete—	
Reinforced canal lining, 3¼ inches thick:	
For canals with 1½:1 side slopes	$0.15 per sq. ft.
For canals with 1¼:1 side slopes	.16 per sq. ft.
Tunnel lining	19.00 per cu. yd.
Siphons, bridges and minor structures, exclusive of reinforcing	15.00 per cu. yd.
Reinforcing steel	.06 per lb.

TABLE 109

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Friant Dam to South Side of Kings River—		
Mile 0 to mile 32.6. Length, 32.6 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 1,820,000 cubic yards at $1.00	$1,820,000	
Earth overlying rock, 1,015,000 cubic yards at $0.25	254,000	
Earth and cobbles, 279,000 cubic yards at $0.60	167,000	
Earth, 286,000 cubic yards at $0.18	52,000	
Rock trimming, 7,187,000 square feet at $0.10	719,000	
Concrete lining, 13,205,000 square feet at $0.16	2,113,000	
Tunnel, 1,400 linear feet at $220	308,000	
Structures:		
Little Dry Creek siphon	176,000	
Dry Creek siphon	19,000	
Kings River siphon	507,000	
Minor siphon	7,000	
Bridges	90,000	
Culverts	59,000	
Main check and wasteway	18,000	
Operation of existing Enterprise Canal during construction	15,000	
Right of ways and fencing	50,000	
		$6,374,000



TYPICAL DESIGN

RIVER SIPHON

AND

TENANT CANAL STRUCTURES

FOR

3000 SECOND-FOOT CANAL

Plate LX, "Typical Conduit Sections of San Joaquin Valley Conveyance Systems," shows hydraulic properties and detail cross sections of the main types of conveyance channels used for a capacity of 3000 second-feet. Designs of typical structures for a canal of 3000 second-feet capacity are presented on Plate LXI, "River Syphon and Appurtenant Canal Structures"; Plate LXII, "Railroad Syphon"; Plate LXIII, "Highway Skew Bridge"; Plate LXIV, "Box Culvert Underdrain"; and Plate LXV, "County Road Bridge."

Cost of San Joaquin River-Kern County Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 109. The estimate sets forth the capital cost of the entire conduit and appurtenant structures, including canals, tunnels, siphons, bridges, other minor structures and right of ways. The total annual cost also is given.

TABLE 108

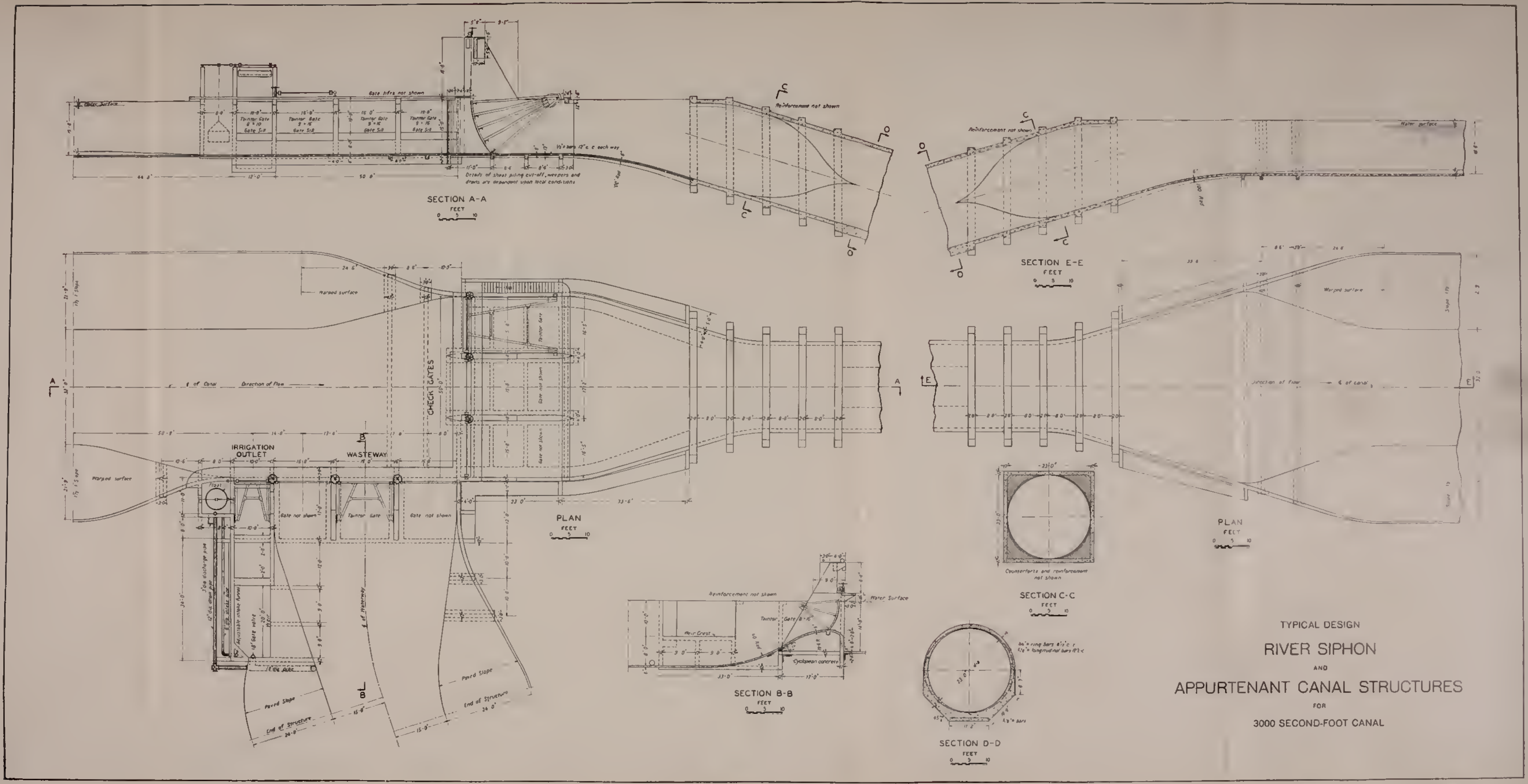
UNIT PRICES USED IN COST ESTIMATES OF SAN JOAQUIN VALLEY CONVEYANCE UNITS

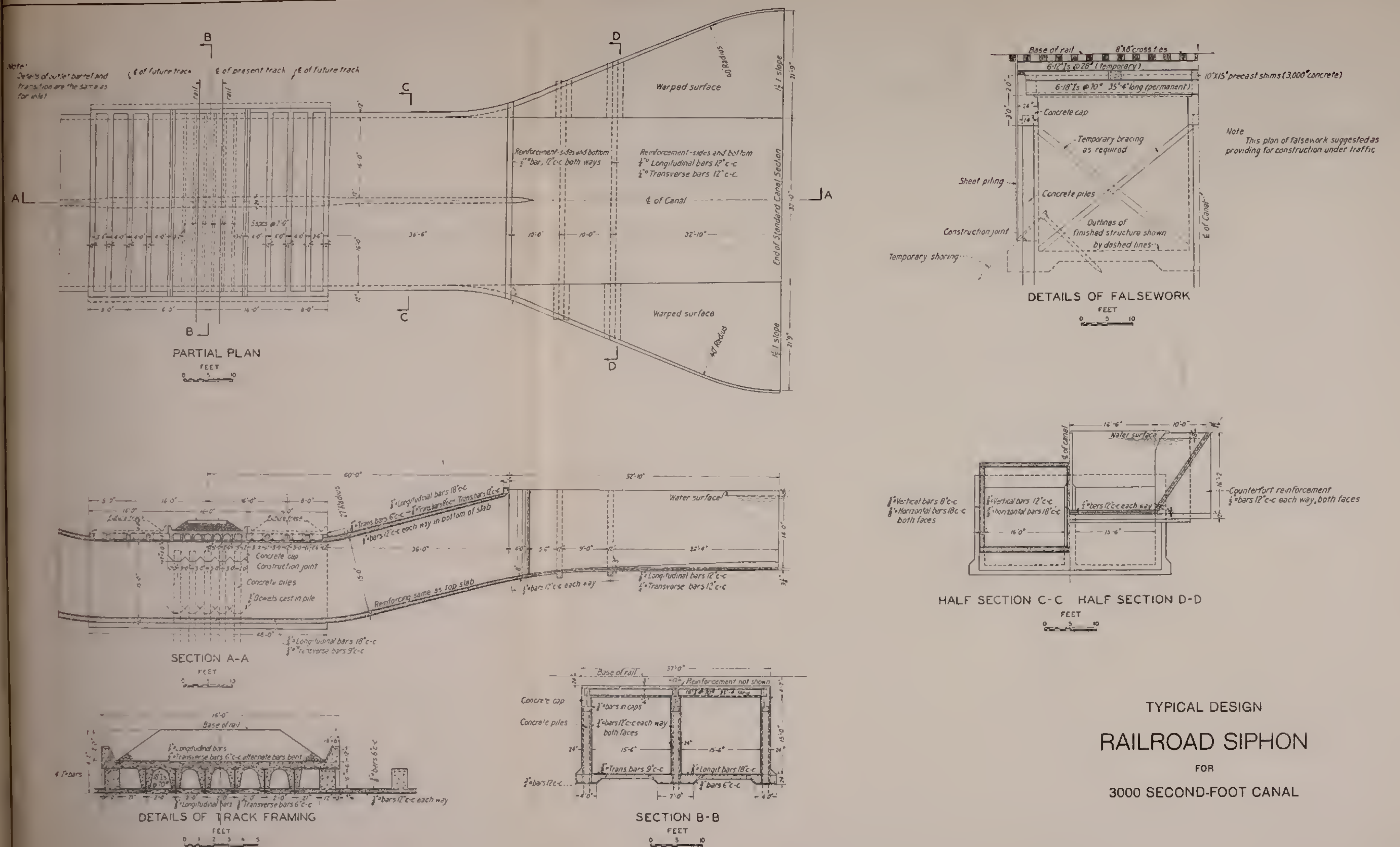
Excavation—	
Canals:	
Rock, exclusive of trimming	$1.00 per cu. yd.
Trimming rock for concrete lining	.10 per sq. ft.
Hardpan	.60 per cu. yd.
Earth and cobble conglomerate	.60 per cu. yd.
Earth overlying rock excavation	.25 per cu. yd.
Earth, typical valley floor classification	.18 per cu. yd.
Tunnels:	
Section sufficiently large for mucking machines. Based on assumptions of ten per cent overbreak and a timbering requirement for 50 per cent of length	$9.00 per cu. yd.
Concrete—	
Reinforced canal lining, 3¼ inches thick:	
For canals with 1½:1 side slopes	$0.15 per sq. ft.
For canals with 1¼:1 side slopes	.16 per sq. ft.
Tunnel lining	19.00 per cu. yd.
Siphons, bridges and minor structures, exclusive of reinforcing	15.00 per cu. yd.
Reinforcing steel	.06 per lb.

TABLE 109

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Friant Dam to South Side of Kings River—		
Mile 0 to mile 32.6. Length, 32.6 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 1,820,000 cubic yards at $1.00	$1,820,000	
Earth overlying rock, 1,015,000 cubic yards at $0.25	254,000	
Earth and cobbles, 279,000 cubic yards at $0.60	167,000	
Earth, 286,000 cubic yards at $0.18	52,000	
Rock trimming, 7,187,000 square feet at $0.10	719,000	
Concrete lining, 13,205,000 square feet at $0.16	2,113,000	
Tunnel, 1,400 linear feet at $220	308,000	
Structures:		
Little Dry Creek siphon	176,000	
Dry Creek siphon	19,000	
Kings River siphon	507,000	
Minor siphon	7,000	
Bridges	90,000	
Culverts	59,000	
Main check and wasteway	18,000	
Operation of existing Enterprise Canal during construction	15,000	
Right of ways and fencing	50,000	
		$6,374,000


SECTION A-A
FEET
SECTION E-E
FEET
PLAN
FEET
CHECK GATES
IRRIGATION OUTLET
WASTEWAY
SECTION B-B
FEET
SECTION C-C
FEET
SECTION D-D
FEET
Reinforcement not shown
Water Surface
Paved Slope
End of Structure
TYPICAL DESIGN
RIVER SIPHON
AND
APPURTENANT CANAL STRUCTURES
FOR
3000 SECOND-FOOT CANAL

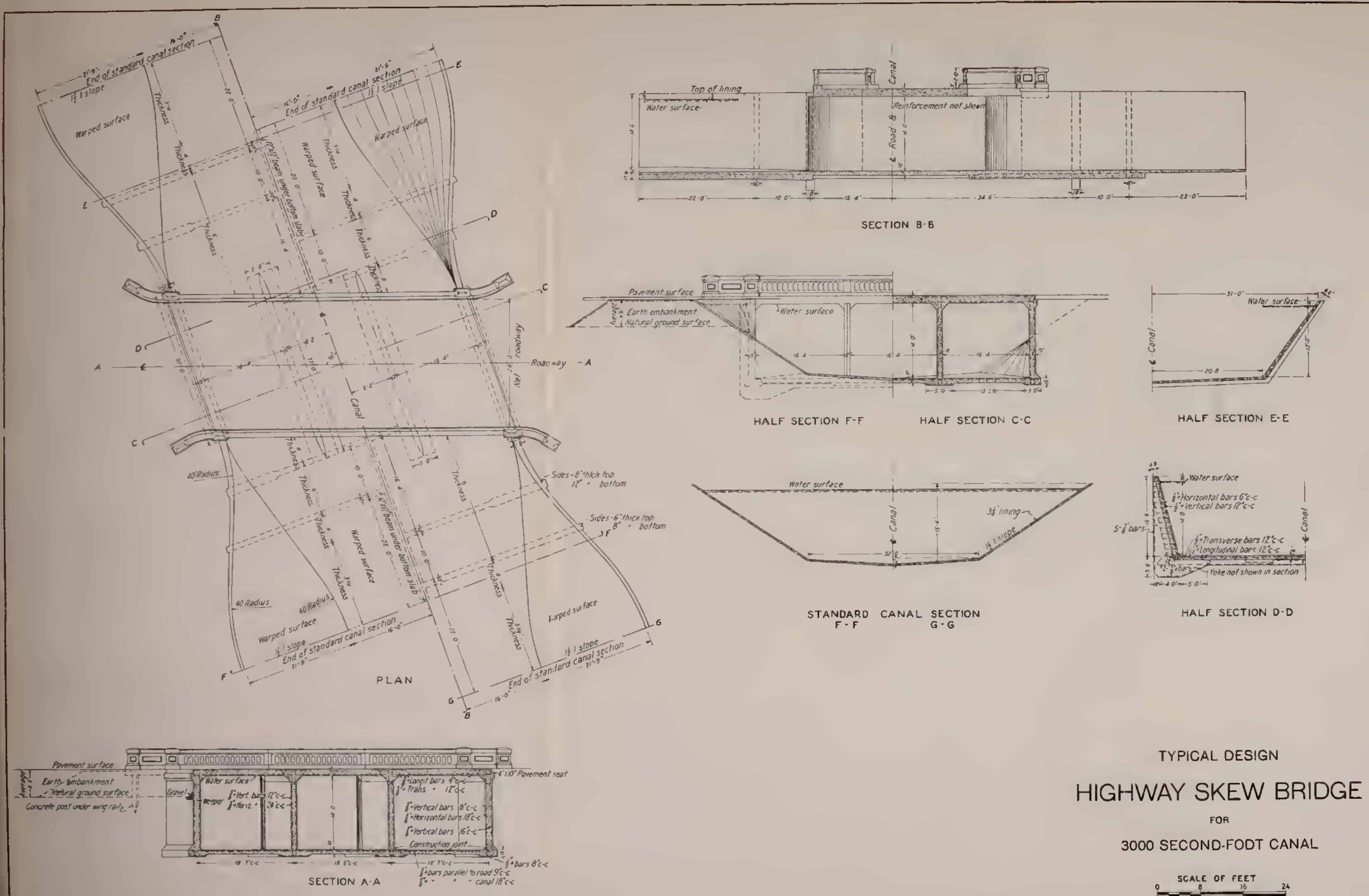


TYPICAL DESIGN

RAILROAD SIPHON

FOR

3000 SECOND-FOOT CANAL

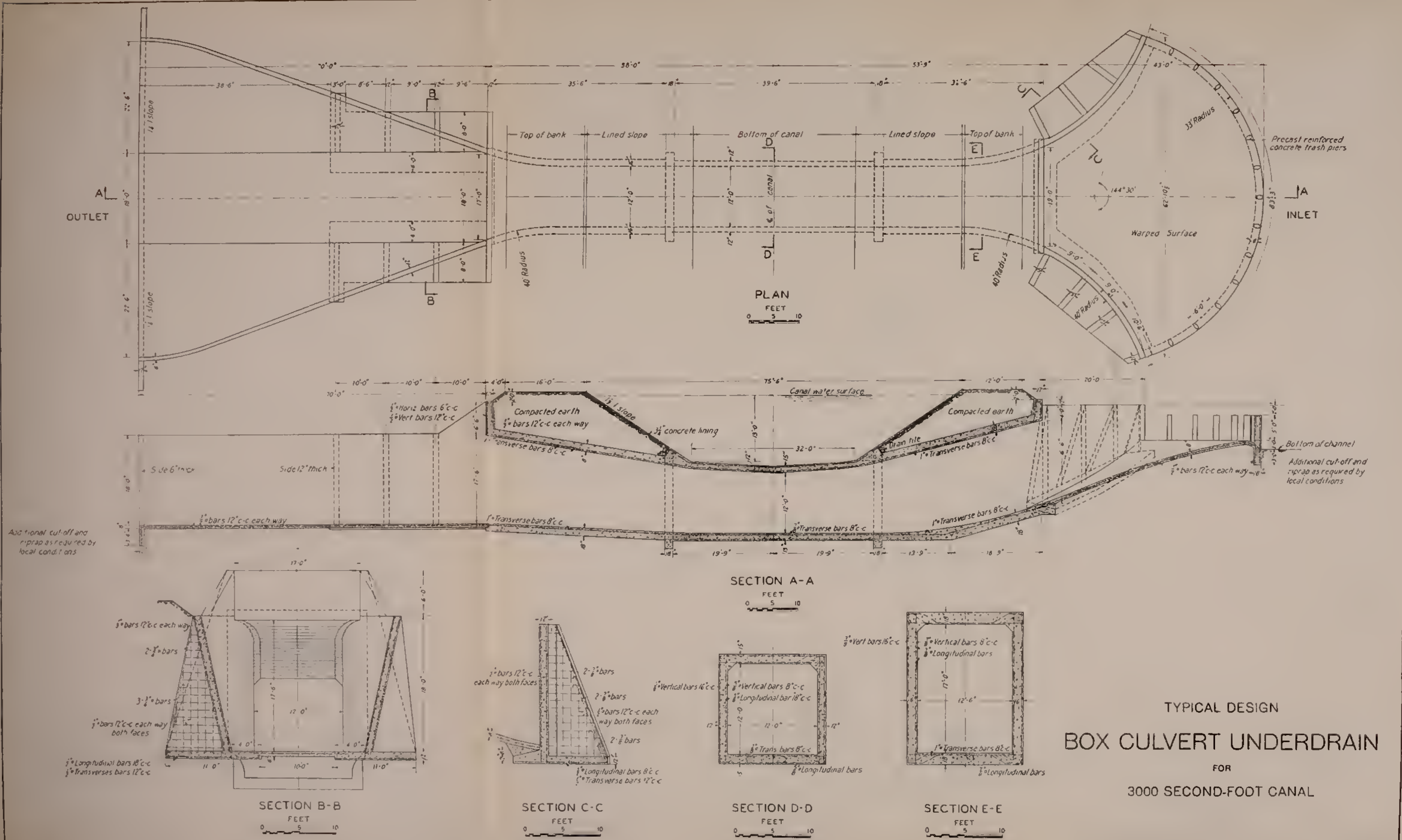


TYPICAL DESIGN

HIGHWAY SKEW BRIDGE

FOR

3000 SECOND-FOOT CANAL

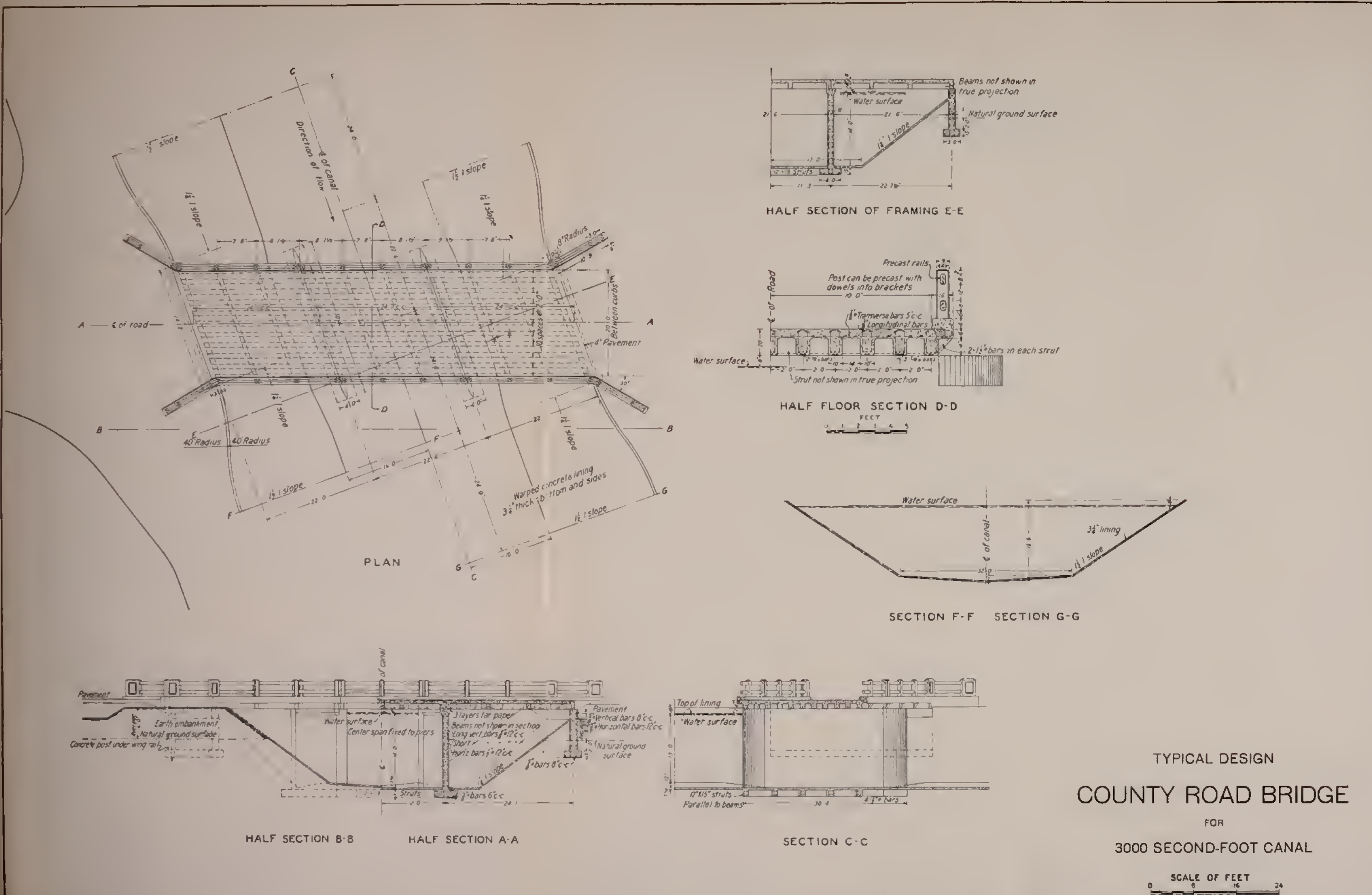


TYPICAL DESIGN

BOX CULVERT UNDERDRAIN

FOR

3000 SECOND-FOOT CANAL



TYPICAL DESIGN

COUNTY ROAD BRIDGE

FOR

3000 SECOND-FOOT CANAL

SCALE OF FEET

TABLE 109—Continued

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Kings River to Cottonwood Creek—		
Mile 32.6 to mile 68.7. Length, 36.1 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 293,000 cubic yards at $1.00	$293,000	
Earth overlying rock, 140,000 cubic yards at $0.25	35,000	
Hardpan, 15,000 cubic yards at $0.60	9,000	
Earth, 2,476,000 cubic yards at $0.18	446,000	
Rock trimming, 2,239,000 square feet at $0.10	224,000	
Concrete lining, 16,271,000 square feet at $0.15	2,441,000	
Tunnel, 300 linear feet at $280	84,000	
Structures:		
Cottonwood Creek siphon	85,000	
Minor siphons	143,000	
Bridges	249,000	
Culverts	129,000	
Main checks and wasteways	22,000	
Right of ways and fencing	370,000	
		$4,530,000
Cottonwood Creek to Tule River—		
Mile 68.7 to mile 98.2. Length, 29.5 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 5,000 cubic yards at $1.00	$5,000	
Hardpan, 69,000 cubic yards at $0.60	41,000	
Earth, 2,197,000 cubic yards at $0.18	396,000	
Rock trimming, 72,000 square feet at $0.10	7,000	
Concrete lining, 13,226,000 square feet at $0.15	1,984,000	
Structures:		
St. Johns River siphon	150,000	
Kaweah River siphon	53,000	
Tule River siphon	74,000	
Minor siphons	144,000	
Bridges	250,000	
Culverts	113,000	
Main checks and wasteways	46,000	
Right of ways and fencing	702,000	
		3,965,000
Tule River to Deer Creek—		
Mile 98.2 to mile 105.3. Length, 7.1 miles. Capacity, 2,500 second-feet.		
Earth excavation, 505,000 cubic yards at $0.18	$91,000	
Concrete lining, 2,983,000 square feet at $0.15	448,000	
Structures:		
Deer Creek siphon	70,000	
Minor siphon	11,000	
Bridges	43,000	
Culverts	8,000	
Main check and wasteway	12,000	
Right of ways and fencing	33,000	
		716,000
Deer Creek to Poso Creek—		
Mile 105.3 to mile 132.0. Length, 26.7 miles. Capacity, 2,000 second-feet.		
Earth excavation, 1,450,000 cubic yards at $0.18	$261,000	
Concrete lining, 10,874,000 square feet at $0.15	1,631,000	
Structures:		
White River siphon	25,000	
Rag Gulch siphon	25,000	
Poso Creek siphon	25,000	
Minor siphons	41,000	
Bridges	169,000	
Culverts	108,000	
Main check and wasteway	11,000	
Right of ways and fencing	147,000	
		2,443,000
Poso Creek to North Side of Kern River—		
Mile 132.0 to mile 155.8. Length, 23.8 miles. Capacity, 1,500 second-feet.		
Earth excavation, 1,061,000 cubic yards at $0.18	$191,000	
Concrete lining, 8,358,000 square feet at $0.15	1,254,000	
Structures:		
Minor siphons	25,000	
Bridges	68,000	
Culverts	59,000	
Main check and wasteway	8,000	
Right of ways and fencing	99,000	
		1,704,000

TABLE 109—Continued

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Kern River to Buena Vista Canal—		
Mile 155.8 to mile 158.7. Length, 2.9 miles. Capacity, 1,000 second-feet.		
Earth excavation, 80,000 cubic yards at $0.18	$14,000	
Concrete lining, 783,000 square feet at $0.15	117,000	
Structures:		
Kern River siphon	59,000	
Bridges	15,000	
Culverts	12,000	
Main check and outlet	9,000	
Right of ways and fencing	8,000	
		$234,000
Buena Vista Canal to Kern Island Canal—		
Mile 158.7 to mile 164.5. Length, 5.8 miles. Capacity, 500 second-feet.		
Earth excavation, 136,000 cubic yards at $0.18	$25,000	
Concrete lining, 1,173,000 square feet at $0.15	176,000	
Structures:		
Minor siphons	13,000	
Bridges	16,000	
Culverts	10,000	
Outlet	5,000	
Right of ways and fencing	27,000	
		272,000
Subtotal		$20,238,000
Administration and engineering, at 10 per cent		2,024,000
Contingencies, at 15 per cent		3,036,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		2,702,000
Total capital cost		$28,000,000
Total annual cost		$2,281,000

Madera Canal.

The Madera Canal is proposed for the conveyance of San Joaquin River water for use on the eastern slope of that part of the upper San Joaquin Valley north of San Joaquin River. With a capacity of 1500 second-feet and a total length of 18 miles, it extends along the eastern rim of the valley between Friant Dam and Fresno River. The location of this canal is shown on Plate XXVI and its profile on Plate LVII.

From the outlet at Friant Dam, at elevation 415 feet, the canal extends in a general southwesterly direction over rough rocky foothill topography for a distance of four miles. The location then turns westerly for a distance of three miles passing through a gap in the main ridge on the south side of Little Table Mountain. It then traverses rolling foothill topography, above and east of the irrigable areas, in a general northeasterly direction for a distance of 11 miles to its terminous at a natural reservoir located in Section 16, Township 10 South, Range 19 East, M. D. B. and M., at elevation 391 feet on the south side of Fresno River. From this point, water would be released for local distribution. The proposed canal is concrete lined for its entire length. It has a water depth of 11.0 feet, a bottom width of 14.0 feet and side slopes of $1\frac{1}{4}$:1. The grade is .0002 feet per foot of length and the velocity would be 5.0 feet per second when conveying the full capacity of 1500 second-feet.

Cost of Madera Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 110. The estimate sets forth the capital cost of the entire conduit and appurtenant structures, including canals, syphons, bridges, other minor structures and right of ways. The total annual cost also is given.

TABLE 110

COST OF MADERA CANAL

Friant Dam to Fresno River

Length, 18 miles. Capacity, 1,500 second-feet.

Excavation:		
Rock, 458,000 cubic yards at $1.00	$458,000	
Earth overlying rock, 560,000 cubic yards at $0.25	140,000	
Rock trimming, 2,540,000 square feet at $0.10	254,000	
Concrete lining, 5,300,000 square feet at $0.16	848,000	
Structures:		
Siphons	70,000	
Bridges and culverts	96,000	
Right of ways and fencing	25,000	
Subtotal		$1,891,000
Administration and engineering, at 10 per cent		189,000
Contingencies, at 15 per cent		284,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		136,000
Total capital cost		$2,500,000
Total annual cost		$213,000

NOTE:—If the Madera Canal were extended a distance of 17 miles from the Fresno to the Chowchilla River, with a capacity of 1000 second-feet to Dalton Creek and a capacity of 500 second-feet from Dalton Creek to Chowchilla River the capital and annual costs would be increased by $800,000 and $65,000 respectively.

Kern River Canal.

A portion of the San Joaquin River water conveyed to the Kern River by the San Joaquin River-Kern County Canal would be utilized on lands now irrigated from Kern River, thus making available Kern River water for use on higher lands which are at present unirrigated and without a water supply. By means of this exchange of supplies the higher lands could be served by gravity diversion from Kern River with a considerable saving in cost as compared to service with imported supplies requiring a high pumping lift. The Kern River Canal is designed to serve these higher lands and would divert a large part of the waters of Kern River to the rim lands around the extreme southern limit of the San Joaquin Valley. The point of diversion for this canal is at elevation 680 feet, about four feet lower than the minimum tail water of the Kern Canyon plant of the San Joaquin Light and Power Corporation. Thus this canal would divert at an elevation of about 311 feet higher than the San Joaquin River-Kern County Canal where it crosses the Kern River. The site of the diversion dam is about 1800 feet downstream from the power house in Section 6, Township 29 South, Range 30 East, M. D. B. and M.

From the diversion site, the canal location extends southwest along the south side of the stream, crosses Cottonwood Creek and, at a point three miles below its head, enters a tunnel 16,000 feet long under the mesa about eight miles east of Bakersfield. The outlet of the tunnel is about two miles north of Edison Station on the Southern Pacific Railway. From this point, the canal extends in a southeasterly direction, crosses the Southern Pacific Railroad about two miles east of Edison and reaches the mile wide channel of Caliente Creek, 15 miles from the point of diversion, at about elevation 660 feet.

The conduit is designed to carry 1500 second-feet for the first 17 miles so that waters in excess of the irrigation draft could be carried during periods of large run-off and used for replenishing the underground reservoir on Caliente Creek Cone.

Based upon the possibilities indicated by preliminary surveys, it is proposed to extend the canal an additional distance of 58 miles, encircling the south end of the valley at the base of the mountain slopes to a point just west of Buena Vista Lake at about elevation 591 feet. Such a location would afford gravity service to lands below an average elevation of 630 feet and with pumping could serve an area of rim lands above the canal. The lengths, water surface elevations, grades, velocities and capacities of various sections of the Kern River Canal are set forth in Table 111. The location of the canal is shown on Plate XXVI and its profile on Plate LVII.

Cost of Kern River Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 112. The estimate sets forth the capital cost of the entire conduit and appurtenant structures including canals, tunnels, siphons, minor structures and right of ways. The total annual cost also is given.

TABLE 111

PHYSICAL FEATURES AND HYDRAULIC ELEMENTS OF KERN RIVER CANAL

Section	Type of conduit	Water surface elevation, in feet	Length of section, in miles	Grade, in feet per foot of length	Velocity of flow at full capacity, in second-feet	Capacity, in second-feet
Mile 0		680.0				
	Concrete lined canal in earth, rock and boulders.		0.4	.00015	4.3	1,500
Mile 0.4		679.4				
	Concrete siphon, 17 feet diameter		0.2	.0006	6.6	1,500
Mile 0.6		678.6				
	Concrete lined canal in earth, rock and boulders.		1.2	.00015	4.3	1,500
Mile 1.8		677.6				
	Concrete siphon, 17 feet diameter		0.2	.0006	6.6	1,500
Mile 2.0		677.1				
	Concrete lined canal in earth, rock and boulders.		1.3	.00015	4.3	1,500
Mile 3.3		676.0				
	Concrete lined tunnel, 16 feet diameter		3.0	.0006	7.2	1,500
Mile 6.3		666.0				
	Concrete lined canal, in earth		11.4	.0001	3.7	1,500
Mile 17.7		660.0				
	Concrete lined canal, on side hill, in earth and rock.		13.0	.00015	4.1	1,200
Mile 30.7		649.2				
	Concrete siphon, 14 feet diameter		0.2	.001	7.8	1,200
Mile 30.9		648.0				
	Concrete lined canal, on side hill, in earth and rock.		3.7	.00015	4 1	1,200
Mile 34.6		645.0				
	Concrete lined canal, in earth		13.3	.0002	4.2	900
Mile 47.9		631.0				
	Concrete lined canal, in earth		12.3	.0002	3.9	600
Mile 60.2		618.0				
	Concrete lined canal, in earth		6.6	.0003	3.8	300
Mile 66.8		607.5				
	Concrete lined canal, in earth		7.6	.0004	3.5	200
Mile 74.4		591.5				

TABLE 112

COST OF KERN RIVER CANAL

Diversion dam		$150,000
Mile 0 to mile 17.7. Length, 17.7 miles. Capacity, 1,500 second-feet.		
Canal excavation:		
Rock, 35,000 cubic yards at $1.00	$35,000	
Earth overlying rock, 114,000 cubic yards at $0.25	28,000	
Earth, 566,000 cubic yards at $0.18	102,000	
Rock trimming, 397,000 square feet at $0.10	40,000	
Concrete lining, reinforced:		
855,000 square feet at $0.16	137,000	
4,020,000 square feet at $0.15	603,000	
Tunnel, concrete lined, 16,000 linear feet at $170.00	2,720,000	
Structures:		
2 major siphons, total length, 2,000 feet	160,000	
1 railroad and highway crossing	20,000	
2 underdrains at Caliente Creek	8,000	
4 secondary road crossings	16,000	
Right of ways and fencing	12,000	
		$3,881,000
Mile 17.7 to mile 34.6. Length, 16.9 miles. Capacity, 1,200 second-feet.		
Canal excavation:		
Rock, 231,000 cubic yards at $1.00	$231,000	
Earth overlying rock, 510,000 cubic yards at $0.25	128,000	
Rock trimming, 2,288,000 square feet at $0.10	229,000	
Concrete lining, reinforced, 4,576,000 square feet at $0.16	732,000	
Structures:		
1 major siphon, total length 1,000 feet	60,000	
4 secondary road crossings	12,000	
5 underdrains	8,000	
Right of ways and fencing	12,000	
		$1,412,000
Mile 34.6 to mile 47.9. Length, 13.3 miles. Capacity, 900 second-feet.		
Canal excavation, earth, 408,000 cubic yards at $0.18	$73,000	
Concrete lining, reinforced, 3,360,000 square feet at $0.15	504,000	
Structures:		
4 secondary road crossings	10,000	
4 underdrains	6,000	
Right of ways and fencing	9,000	
		$602,000
Mile 47.9 to mile 60.2. Length, 12.3 miles. Capacity, 600 second-feet.		
Canal excavation, earth, 307,000 cubic yards at $0.18	$55,000	
Concrete lining, reinforced, 2,665,000 square feet at $0.15	400,000	
Structures:		
2 secondary road crossings	4,000	
2 underdrains	2,000	
Right of ways and fencing	8,000	
		$469,000
Mile 60.2 to mile 66.8. Length, 6.6 miles. Capacity, 300 second-feet.		
Canal excavation, earth, 97,000 cubic yards at $0.18	$17,000	
Concrete lining, reinforced, 1,050,000 square feet at $0.15	158,000	
Structures:		
2 secondary road crossings	3,000	
2 underdrains	2,000	
Right of ways and fencing	4,000	
		$184,000
Mile 66.8 to mile 74.4. Length, 7.6 miles. Capacity, 200 second-feet.		
Canal excavation, earth, 56,000 cubic yards at $0.18	$10,000	
Concrete lining, reinforced 1,000,000 square feet at $0.15	150,000	
Structures:		
2 secondary road crossings	3,000	
1 single track railroad crossing	3,000	
2 underdrains	1,000	
Right of ways and fencing	5,000	
		$172,000
Subtotal		$6,870,000
Administration and engineering, at 10 per cent		687,000
Contingencies, at 15 per cent		1,031,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		412,000
Total capital cost		$9,000,000
Total annual cost		$721,000

Mendota-West Side Pumping System.

To make water available for the good land lying on the western slope of the upper San Joaquin Valley would require a pumping system extending from Mendota Pool to Elk Hills. Water for this area would be conveyed to Mendota through the San Joaquin River Pumping System. The conveyance channel required for full development would be 100 miles long and would have a capacity varying from 4500 to 500 second-feet.

The proposed Mendota-West Side Pumping System departs from the Mendota Pool at elevation 159 feet, with a constructed canal extending southerly along the most favorable topography. By means of two pumping lifts in a distance of three miles the water is raised to an elevation of 207.0 feet at the discharge of Plant No. 2. The capacity is reduced at this point to 3500 second-feet and the canal continues to Plant No. 3 located at Mile 20. By means of Plants No. 3 and No. 4 the water is raised to an elevation of 248.0 feet at Mile 21 and the canal continues to Mile 32 where the capacity is reduced to 2500 second-feet. Plants No. 5 and No. 6 raise the water to an elevation of 272 feet at Mile 68, where the canal capacity is reduced to 1500 second-feet. This capacity continues to Mile 90 where it is reduced to 500 second-feet and the canal continues at this latter capacity to its terminus at Mile 100 at elevation 250.0 feet. At each point of reduction in capacity local distribution systems, consisting of pumping plants and conveyance channels, would be required. At Mile 19, Mile 32, Mile 66, Mile 90 and Mile 100, spillway channels extending to the valley trough are provided, with capacities of 3500, 1000, 2500, 1000, and 500 second-feet respectively, and with lengths varying from three to eight miles.

Minor structures comprise one set of intake gates at Mendota Pool, two railroad siphons, five highway bridges, 61 county road bridges, three canal control structures and five spillway structures. Pumping plants are of the same type as shown for the San Joaquin River Pumping System on Plate LVIII. The height of each lift and the capacity of each pumping plant are set forth in Table 113. The seasonal amount of water to be pumped through each lift and the estimated seasonal energy consumption also are given in the tabulation.

TABLE 113

PUMPING LIFTS AND CAPACITIES, SEASONAL QUANTITY OF WATER PUMPED AND SEASONAL ENERGY CONSUMPTION FOR MENDOTA-WEST SIDE PUMPING SYSTEM

Pumping plant number	Location of plant	Height of lift, in feet	Capacity of plant, in second-feet	Seasonal quantity of water pumped, in acre-feet	Seasonal energy consumption, in kilowatt hours
1	Mile 2	25	4,500	1,544,000	65,910,00
2	Mile 3	25	4,500	1,544,000	65,910,00
3	Mile 20	25	3,500	1,201,000	51,268,00
4	Mile 21	25	3,500	1,201,000	51,268,00
5	Mile 67	25	2,500	858,000	36,626,00
6	Mile 68	25	2,500	858,000	36,626,00
	Totals	150			307,608,00
	Average weighted lift	117			

Cost of Mendota-West Side Pumping System—An estimate of cost, based on unit prices set forth in Table 105 for San Joaquin River Pumping System, is presented in Table 114. The estimate sets forth the capital cost of the complete pumping system including canals, pumping plants, spillway channels, minor structures and right of ways. The total annual cost, including the average annual charge for electric energy, also is given in the tabulation.

TABLE 114

COST OF MENDOTA-WEST SIDE PUMPING SYSTEM

Length, 100 miles. Capacity varies from 4,500 to 500 second-feet.

Excavation:		
Canals in deep cut and fill sections near pumping plants, 1,890,000 cubic yards at $0.20 to $0.23	$400,000	
Canals with regular concrete lined section, 6,514,000 cubic yards at $0.18	1,172,000	
Spillway channels, 2,644,000 cubic yards at $0.18	476,000	
		$2,048,000
Reinforced concrete canal lining:		
39,309,000 square feet at $0.15		5,897,000
Pumping plants:		
Lift No. 1, capacity 4,500 second-feet	612,000	
Lift No. 2, capacity 4,500 second-feet	612,000	
Lift No. 3, capacity 3,500 second-feet	476,000	
Lift No. 4, capacity 3,500 second-feet	476,000	
Lift No. 5, capacity 2,500 second-feet	340,000	
Lift No. 6, capacity 2,500 second-feet	340,000	
		2,856,000
Structures:		
On portion of canal having a capacity of 4,500 second-feet:		
Control works in cut from Mendota Pool	40,000	
Highway and railroad crossing	55,000	
County road bridge	10,000	
On portion of canal having a capacity of 3,500 second-feet:		
Control structure	15,000	
Highway bridges, 2 at $11,000	22,000	
County road bridges, 13 at $8,000	104,000	
Spillway structure, capacity 3,500 second-feet	12,000	
Spillway structure, capacity 1,000 second-feet	5,000	
On portion of canal having a capacity of 2,500 second-feet:		
Control structure	10,000	
Highway bridges, 2 at $9,000	18,000	
County road bridges, 15 at $6,000	90,000	
Railroad crossing	20,000	
Spillway structure	8,000	
On portion of canal having a capacity of 1,500 second-feet:		
County road bridges, 10 at $5,000	50,000	
Spillway structure	4,000	
On portion of canal having a capacity of 500 second-feet:		
County road bridges, 4 at $3,000	12,000	
Control structure	3,000	
Spillway structure	3,000	
On spillway channels:		
County road bridges on spillway channel having a capacity of 3,500 second-feet, 4 at $4,000	16,000	
County road bridges on spillway channel having a capacity of 2,500 second-feet, 3 at $3,000	9,000	
County road bridges on spillway channels having a capacity of 1,000 second-feet, 7 at $2,000	14,000	
County road bridges on spillway channel having a capacity of 500 second-feet, 4 at $1,500	6,000	
		526,000
Right of ways and fencing		240,000
Subtotal		$11,567,000
Administration and engineering, at 10 per cent		1,156,000
Contingencies, at 15 per cent		1,735,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,542,000
Total capital cost		$16,000,000
Annual cost exclusive of energy		$1,396,000
Average annual energy charge, 307,608,000 kilowatt-hours at $0.0055		1,692,000
Total annual cost		$3,088,000

Summary of Conveyance Units.

A summary of the cost estimates and principal physical features of all the major conveyance units of the Ultimate State Plan in the San Joaquin River Basin has been compiled from the foregoing estimates and data and is set forth in Table 115. The length, capacity, number of pumping plants, elevations of diversion and terminus, maximum and average weighted pumping lifts, capital costs of various features and annual costs, exclusive and inclusive of energy charges, are set forth in the tabulation for each unit.

SUMMARY OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

In the foregoing pages of this chapter there has been presented a discussion, description and estimates of capital and annual costs of each major storage and conveyance unit of the Ultimate State Water Plan in the San Joaquin River Basin. Table 99 sets forth a somewhat detailed summary of the main physical features and principal items of capital and annual costs of surface storage reservoirs and power plants. Corresponding data for conveyance units have been summarized in Table 115.

In Table 100, the total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the San Joaquin Valley are set forth, first, between a depth of 10 feet below ground surface and the underground water level of 1929, second, between depths of 10 and 50 feet below ground surface and third, between depths of 10 feet below ground surface and the assumed economic limit of pumping. The available and utilizable underground storage capacity in the upper San Joaquin Valley would be operated to obtain the fullest practicable beneficial use of the local and imported supplies. The results of analyses of the cost of ground water pumping for various sizes of installation, heights of lift and periods of operation have been set forth in Table 101. The general average values, for estimating the cost of ground water pumping in the upper San Joaquin Valley, have been determined as two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for power charges or a total of five cents per foot acre-foot.

Table 116 sets forth the capital and net annual costs of all major surface storage and conveyance units in the San Joaquin River Basin. Plans for four of the reservoirs include power plants. The net annual cost is obtained by deducting from the gross annual cost of the reservoir and power plant the anticipated average annual revenue from the sale of electric energy. Two of the conveyance units include pumping systems. The net annual cost of each of these units includes the estimated average annual cost of electric energy required for pumping.

ATER PLAN IN SAN JOAQUIN RIVER BASIN

	...inistra-n, engi-ring and ...ingencies	Interest during construction	Total	Annual cost		
				Exclusive of electric energy for pumping	Electric energy for pumping	Total
Sacramen... Hood t...	757,000	$217,000	$4,000,000	$300,000	0	$300,000
San Joaq...	150,000	2,750,000	28,500,000	2,539,000	$4,240,000	6,779,000
San Joaq...	060,000	2,702,000	28,000,000	2,281,000	0	2,281,000
Madera (...	473,000	136,000	2,500,000	213,000	0	213,000
Kern Riv...	718,000	412,000	9,000,000	721,000	0	721,000
Mendota...	891,000	1,542,000	16,000,000	1,396,000	1,692,000	3,088,000
Tota...	049,000	$7,759,000	$88,000,000	$7,450,000	$5,932,000	$13,382,000

Summary of Conveyance Units.

A summary of the cost estimates and principal physical features of all the major conveyance units of the Ultimate State Plan in the San Joaquin River Basin has been compiled from the foregoing estimates and data and is set forth in Table 115. The length, capacity, number of pumping plants, elevations of diversion and terminus, maximum and average weighted pumping lifts, capital costs of various features and annual costs, exclusive and inclusive of energy charges, are set forth in the tabulation for each unit.

SUMMARY OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

In the foregoing pages of this chapter there has been presented a discussion, description and estimates of capital and annual costs of each major storage and conveyance unit of the Ultimate State Water Plan in the San Joaquin River Basin. Table 99 sets forth a somewhat detailed summary of the main physical features and principal items of capital and annual costs of surface storage reservoirs and power plants. Corresponding data for conveyance units have been summarized in Table 115.

In Table 100, the total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the San Joaquin Valley are set forth, first, between a depth of 10 feet below ground surface and the underground water level of 1929, second, between depths of 10 and 50 feet below ground surface and third, between depths of 10 feet below ground surface and the assumed economic limit of pumping. The available and utilizable underground storage capacity in the upper San Joaquin Valley would be operated to obtain the fullest practicable beneficial use of the local and imported supplies. The results of analyses of the cost of ground water pumping for various sizes of installation, heights of lift and periods of operation have been set forth in Table 101. The general average values, for estimating the cost of ground water pumping in the upper San Joaquin Valley, have been determined as two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for power charges or a total of five cents per foot acre-foot.

Table 116 sets forth the capital and net annual costs of all major surface storage and conveyance units in the San Joaquin River Basin. Plans for four of the reservoirs include power plants. The net annual cost is obtained by deducting from the gross annual cost of the reservoir and power plant the anticipated average annual revenue from the sale of electric energy. Two of the conveyance units include pumping systems. The net annual cost of each of these units includes the estimated average annual cost of electric energy required for pumping.

TABLE 115

SUMMARY OF MAIN PHYSICAL FEATURES AND PRINCIPAL ITEMS OF COST OF MAJOR CONVEYANCE UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Length, in miles	Maximum capacity, in second-feet	Elevation in feet, U. S. G. S. datum		Pumping plants			Capital cost							Annual cost		
			Point of diversion	Terminus	Number	Maximum lift, in feet	Average weighted lift, in feet	Pumping plants	Diversion, control and other structures	Main conveyance channels	Right of ways	Administration, engineering and contingencies	Interest during construction	Total	Exclusive of electric energy for pumping	Electric energy for pumping	Total
Sacramento-San Joaquin Delta Cross Channel, Hood to Central Landing	24	10,000							$2,676,000	$200,000	$150,000	$757,000	$217,000	$4,000,000	$300,000	0	$300,000
San Joaquin River Pumping System	165	8,000	0	159	10	202	185	$8,988,000	1,703,000	9,195,000	714,000	5,150,000	2,750,000	28,500,000	2,539,000	$4,240,000	6,779,000
San Joaquin River-Kern County Canal	165	3,000	467	358					3,196,000	15,606,000	1,436,000	5,060,000	2,702,000	28,000,000	2,281,000	0	2,281,000
Madera Canal	18	1,500	415	391					166,000	1,700,000	25,000	473,000	136,000	2,500,000	213,000	0	213,000
Kern River Canal	75	1,500	680	591					468,000	6,352,000	50,000	1,718,000	412,000	9,000,000	721,000	0	721,000
Mendota-West Side Pumping System	100	4,500	159	250	6	150	117	2,856,000	526,000	7,945,000	240,000	2,891,000	1,542,000	16,000,000	1,396,000	1,602,000	3,088,000
Totals	547				16			$11,844,000	$8,735,000	$40,998,000	$2,615,000	$16,049,000	$7,759,000	$88,000,000	$7,450,000	$5,932,000	$13,382,000

TABLE 116

SUMMARY OF COSTS OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Location	Capital cost	Net annual cost
Surface Storage Units			
Nashville Reservoir	Cosumnes River	$7,400,000	$441,000
Ione Reservoir	Dry Creek	8,600,000	517,000
Pardee Reservoir	Mokelumne River	Constructed	Constructed
Valley Springs Reservoir	Calaveras River	7,600,000	452,000
Melones Reservoir[1]	Stanislaus River	26,200,000	937,000
Don Pedro Reservoir[1]	Tuolumne River	32,500,000	979,000
Exchequer Reservoir	Merced River	Constructed	Constructed
Buchanan Reservoir	Chowchilla River	2,600,000	155,000
Windy Gap Reservoir	Fresno River	3,300,000	200,000
Friant Reservoir[2]	San Joaquin River	14,500,000	805,000
Pine Flat Reservoir[1]	Kings River	11,600,000	541,000
Pleasant Valley Reservoir	Tule River	2,900,000	171,000
Isabella Reservoir	Kern River	5,700,000	340,000
Subtotals		$122,900,000	$5,538,000
Conveyance Units			
Sacramento-San Joaquin Delta Cross Channel	Sacramento-San Joaquin Delta	$4,000,000	$300,000
San Joaquin River Pumping System	West side lower San Joaquin Valley	28,500,000	[3]6,779,000
Mendota-West Side Pumping System	West side upper San Joaquin Valley	16,000,000	[4]3,088,000
Madera Canal	East side upper San Joaquin Valley, north of San Joaquin River	2,500,000	213,000
San Joaquin River-Kern County Canal	East side upper San Joaquin Valley, south of San Joaquin River	28,000,000	2,281,000
Kern River Canal	East side and south end of upper San Joaquin Valley, south of Kern River	9,000,000	721,000
Subtotals		$88,000,000	$13,382,000
Totals, all units		$210,900,000	$18,920,000

[1] Includes power plant.
[2] Includes power plant for ultimate development, only.
[3] Includes energy cost of $4,240,000.
[4] Includes energy cost of $1,692,000.

CHAPTER VII

OPERATION AND ACCOMPLISHMENTS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

The operation and accomplishments of the ultimate State Water Plan in the San Joaquin River Basin are closely related to and interdependent with those in the plan for the Sacramento River Basin because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for a portion of the supply required to meet its ultimate water requirements. The ultimate water requirements of the San Joaquin River Basin are materially in excess of the water supplies which could be made available from local tributary sources by full practicable development and utilization. The logical source of supplemental water supply is the Sacramento River Basin where a surplus over and above the full ultimate water requirements in that basin, including the Sacramento-San Joaquin Delta, would be made available by the major units proposed for ultimate development therein. The ultimate State Water Plan proposes to import surplus water from the Sacramento River Basin to meet the deficiency between available local supply and ultimate demand in the San Joaquin River Basin. Accordingly, consideration of the operation and accomplishments of the plan in the San Joaquin River Basin must be combined with those in the Sacramento River Basin. The proposed major units for ultimate development in the two basins constitute a unified project for the entire Great Central Valley. It is proposed to operate these major units coordinately to provide the ultimate water requirements and to accomplish the objectives sought for the fullest practicable development, regulation, distribution and utilization of the water resources.

Objectives of Ultimate State Water Plan in Great Central Valley.

The primary objective of the ultimate State Water Plan in the Great Central Valley is to provide a water supply sufficient in amount and with suitable rates of delivery to meet the ultimate water requirements for all purposes, including domestic and municipal supply, industrial supply, irrigation, salinity control, navigation, hydroelectric power development and other desirable and necessary uses. In addition to supplying water for these purposes in the Great Central Valley, it is proposed to furnish the supplemental water supply required in the adjacent San Francisco Bay Basin from supplies developed within the Great Central Valley Basin. It is also proposed to provide additional flood protection required for the lands in the Sacramento and San Joaquin valleys. Navigation would be improved on both the Sacramento and San Joaquin rivers. Hydroelectric power development would be made in connection with major surface storage reservoirs where economically feasible and giving promise of yielding revenues from sale of electric energy which would assist in defraying the cost of the project. The plan for ultimate development provide for the conservation, regulation, distribution and utilization of the available water resources to accomplish these desirable and necessary objectives.

Major Units of Ultimate State Water Plan in Great Central Valley.

The ultimate State Water Plan in the Great Central Valley provides for surface and underground storage to regulate the run-off of the major streams to supply the water requirements for irrigation and other necessary purposes. In addition to the surface storage units on the major streams in the Great Central Valley Basin, a storage reservoir on the Trinity River with works for diversion of the regulated supplies therefrom into the Sacramento River Basin are provided to augment the available water supply in the Great Central Valley. Conduits are provided to convey surplus water from the Sacramento River Basin to the areas of deficient supply in the San Joaquin Valley. Other conveyance conduits from the San Joaquin and Kern rivers are provided in the plan for the purpose of effecting an exchange between imported and local supplies in accord with the most economical plan of development.

The major units of the ultimate State Water Plan in the Great Central Valley are summarized in Table 117 and are shown on Plate XXVI. Those in the Sacramento River Basin are described in another report.* The major storage and conveyance units in the San Joaquin River Basin have been descried in detail in Chapter VI.

TABLE 117

MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY

Storage Units

Reservoir	Stream on which reservoir is located	Height of main dam, in feet	Capacity of reservoir, in acre-feet	Installed capacity of power plants, in kilovolt amperes
Sacramento River Basin				
Kennett	Sacramento River	520	5,967,000	450,000
Oroville	Feather River	580	1,705,000	314,000
Narrows	Yuba River	580	853,000	160,000
Camp Far West	Bear River	180	151,000	
Auburn	American River	440	831,000	110,000
Coloma	American River	345	766,000	60,000
Folsom	American River	190	355,000	125,000
Fairview (Trinity River diversion)	Trinity River	365	1,436,000	193,000
Millsite	Stony Creek	135	115,000	
Capay	Cache Creek	170	378,000	
Monticello	Putah Creek	150	130,000	
San Joaquin River Basin				
Nashville	Cosumnes River	270	281,000	
Ione	Dry Creek	120	610,000	
Pardee	Mokelumne River	343	222,000	18,750
Valley Springs	Calaveras River	200	325,000	
Melones	Stanislaus River	460	1,090,000	[1]68,000
Don Pedro	Tuolumne River	455	1,000,000	[2]120,000
Exchequer	Merced River	307	279,000	31,250
Buchanan	Chowchilla River	147	84,000	
Windy Gap	Fresno River	206	62,000	
Friant	San Joaquin River	252	[3]400,000	[4]10,000
Pine Flat	Kings River	274	400,000	40,000
Pleasant Valley	Tule River	125	39,000	
Isabella	Kern River	190	338,000	
Totals			17,817,000	1,700,000

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

TABLE 117—Continued

Conveyance Units

Unit	Maximum capacity, in second-feet	Length, in miles
San Joaquin River Basin		
Sacramento-San Joaquin Delta cross channel		24
San Joaquin River pumping system	8,000	167
Madera canal	1,500	18
San Joaquin River-Kern County canal	3,000	165
Kern River canal	1,500	75
Mendota-West Side pumping system	4,500	100
Total		549

[1] Present installed capacity 27,000 kilovolt amperes.
[2] Present installed capacity 33,740 kilovolt amperes.
[3] Effective capacity 270,000 acre-feet.
[4] A 30,000 kilovolt ampere power plant would be constructed on the river and the cost thereof amortized in ten years. A 10,000 kilovolt ampere plant would then be constructed on the Madera canal to utilize the power drop at the dam into that canal after water is no longer available for the larger river plant.

In addition to the major surface storage and conveyance units in the San Joaquin River Basin, the underground storage reservoirs, particularly in the upper San Joaquin Valley, are an essential feature of the proposed plan of development. The utilization of these underground reservoirs for storage and subsequent extraction of water supplies by pumping is of fundamental importance. The area, location and utilizable capacity of these underground reservoirs have been presented in detail in Chapter VI, together with data on the cost of utilization by pumping.

Operation and Accomplishments of Ultimate State Water Plan in Great Central Valley.

In order to accomplish the objectives sought and desired under the ultimate State Water Plan for the Great Central Valley, the major units for storage, both surface and underground, and for conveyance would be operated coordinately under a unified plan of development. The proposed major units in the Sacramento River Basin would be operated not only to take care of the requirements for all purposes within that basin itself, including the Sacramento-San Joaquin Delta, but also would be operated coordinately with the major units in the San Joaquin River Basin to provide the supplemental supplies required therein.

The ultimate water requirements are governed chiefly by the requirements for irrigation which now use more than 90 per cent of the water developed and utilized in this area and which probably will continue to predominate in like proportion. The required ultimate water supply, with the exception of that for special uses such as navigation improvement and salinity control, is based upon the requirements for irrigation. The supply provided on this basis would be ample for domestic, municipal and industrial uses in areas in which water is required for these purposes.

Within the Sacramento River Basin where ample water supplies are available, it is proposed to furnish, under the ultimate plan of development, a full surface irrigation supply without deficiency for the ultimate needs of the entire basin, including valley floor, foothill and mountain valley agricultural lands. In addition, it is proposed to furnish from surplus waters of the Sacramento River Basin and from such waters as reach the delta from the San Joaquin River Basin a full supply without deficiency for the Sacramento-San Joaquin Delta to meet the consumptive demands therein and to keep the water in the delta channels fresh by preventing saline invasion from the bay into the delta channels; a supplemental supply for the San Francisco Bay Basin, with some deficiency in an exceptionally dry year in the portion of the supply provided for irrigation; and finally a supplemental supply for the areas deficient in local supply in the San Joaquin Valley. It is proposed to improve navigation on the Sacramento River by providing adequate and dependable navigation depths from Sacramento to Red Bluff. This improvement would be effected by the provision of a regulated flow in the river sufficient in amount, if coupled with open channel improvements, to maintain required depths for commercial navigation. It is also proposed to provide additional flood protection which is desirable and necessary for the lands in the Sacramento Valley, by the reservation and utilization of storage space in the major reservoirs for flood regulation during the flood season.

Within the San Joaquin River Basin, the ultimate plan of development proposes to furnish irrigation supplies to meet the ultimate requirements in varying degree in different portions of the basin. In general, for the irrigable areas to be served under the ultimate State Water Plan as set forth in Chapter VI, it is proposed to furnish a surface irrigation supply with a maximum deficiency of 35 per cent in an exceptionally dry year for the lands in the lower San Joaquin Valley and on the west side of the upper San Joaquin Valley. On the eastern side of the upper San Joaquin Valley, through the combined means of surface storage and underground storage and pumping, it is proposed to furnish practically a full supply without deficiency for the irrigable lands to be served under the ultimate State Water Plan. The ultimate water requirements for the areas to be served under the ultimate State Water Plan in the San Joaquin River Basin have been presented in Chapter V and will be referred to subsequently in this chapter in the detailed presentation of the operation and accomplishments of the plan.

Additional flood protection which is desirable and necessary for the lands in the San Joaquin Valley is proposed to be effected through the reservation and utilization of storage space in several major surface reservoirs for the regulation of floods during the flood season. In addition, it is proposed to improve navigation on the San Joaquin River above Stockton by means of canalization by dams equipped with locks. The San Joaquin River Pumping System, as designed most economically for irrigation service primarily, includes a series of dams which would canalize the river to Hills Ferry and provide adequate navigation depths. The dams would be equipped with locks for this purpose. The San Joaquin River Pumping System could be extended from Hills Ferry to Mendota with dams and pumping lifts in the river channel as in the section below Hills Ferry and thus canalize the river and provide for navigation to Mendota if the dams were equipped with locks. Although this would entail greater expense than the canal plan provided in the proposed San Joaquin River Pumping System between Hills Ferry and Mendota, it might prove desirable and feasible if the additional cost could be provided for in the interest of navigation. A more detailed consideration of navigation improvement on the upper San Joaquin River is presented in Chapter X.

Three methods of operation of the major units of the ultimate plan have been considered and are presented in detail in other reports.* Under the method designated "II" in the reports cited, which may be considered to be best adapted to the accomplishments sought, the proposed plan of operation and the accomplishments are summarized briefly as follows:

1. The amount of water utilized for storage and regulation in the major reservoir units and underground storage basins was obtained by deducting from the full natural run-off of the streams entering the Great Central Valley, the net use of 2,283,000 acre-feet per season for an adequate and dependable irrigation supply for 1,439,000 acres of land, being the net irrigable mountain valley and foothill lands lying at elevations too high to be irrigated by gravity from the major reservoir units, thus providing for the ultimate needs of these areas; and also deducting 448,000 acre-feet per year from the Tuolumne River for the water supply of the city of San Francisco. An additional amount of 224,000 acre-feet per year also was deducted for the San Francisco Bay Basin from water regulated in Pardee Reservoir on the Mokelumne River.

2. Reserve storage space would have been held in the reservoirs listed in Table 118 for controlling floods. The amount of this space and the regulated flow to which floods on each stream would have been controlled also are shown in the same table.

3. Stored water would have been drawn from the major surface reservoir units, and underground basins in the upper San Joaquin Valley, in such amounts and at such times as to supplement unregulated flows and return waters, to make water available for:

   a. A supply of 9,033,000 acre-feet per season, gross allowance, without deficiency, available in the principal streams, for the irrigation of all of the net area of 2,640,000 acres of irrigable lands of all classes on the Sacramento Valley floor.
   b. A supply of 1,200,000 acre-feet per season, without deficiency, for the irrigation of all the net area of 392,000 acres of irrigable lands, and for unavoidable losses, in the Sacramento-San Joaquin Delta.
   c. Improvement of navigation on Sacramento River to Red Bluff.
   d. A fresh water flow of not less than 3300 second-feet past Antioch into Suisun Bay, which would have controlled salinity to the lower end of the Sacramento-San Joaquin Delta.

* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930, and
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

e. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent, for the irrigation of all the net area of 1,810,000 acres of irrigable land of all classes in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley below the major reservoirs.

f. A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of class 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley. This would have been accomplished by the utilization of underground storage capacity in conjunction with the major reservoir and conveyance units proposed.

g. A supply of 1,570,000 acre-feet per season, with a maximum deficiency of 35 per cent, for the irrigation of all the net irrigable area of 785,000 acres of class 1 and 2 lands lying chiefly on the western slope of the upper San Joaquin Valley.

h. A water supply and channel depth in the San Joaquin River sufficient to provide a navigable depth of six feet as far upstream as Salt Slough, nine miles above the Merced River.

i. A supply of 403,000 acre-feet per season in the Sacramento-San Joaquin Delta, for use in the San Francisco Bay Basin. There would have been a deficiency of 35 per cent in 1924 in the 323,000 acre-foot portion of this supply allotted to use for irrigation. This amount of 403,000 acre-feet per season, together with full practicable development of local resources and annual importations of 224,000 acre-feet from the Mokelumne River and 448,000 acre-feet from the Tuolumne River, and an importation from the Eel River, would have given an adequate and dependable supply for the ultimate development of this basin.

j. The generation of more than five billion kilowatt hours of electric energy, on the average, annually.

Table 118 sets forth the streams on which flood control by reservoirs is proposed, the maximum reservoir space required to regulate winter floods to certain controlled flows, the amount of the controlled flows, and the frequency with which the controlled flows would be exceeded. The operation of all these reservoirs specifically for flood control, employing the reservoir space assigned to each reservoir for the purpose of controlling floods to the specified flows, would result in a substantial reduction in flood flows and in an increased degree of protection to the areas subject to overflow in the Sacramento and San Joaquin valleys, and therefore would decrease the potential annual flood damages in those areas.

TABLE 118

RESERVOIR SPACE REQUIRED FOR CONTROLLING WINTER FLOODS TO CERTAIN SPECIFIED FLOWS

Reservoir	Stream	Point of control	Maximum reservoir space employed, in acre-feet	Controlled flow, in second-feet	Number of times controlled flow would be exceeded on the average
Kennett	Sacramento River	Red Bluff	512,000	[2]125,000	Once in 14 years
Oroville	Feather River	Oroville	521,000	100,000	Once in 100 years
Narrows	Yuba River	Smartsville	272,000	70,000	Once in 100 years
Camp Far West	Bear River	Wheatland	50,000	20,000	Once in 100 years
Folsom, Auburn and Coloma	American River	Fairoaks	300,000	[3]80,000	One day in 250 yrs.
Nashville	Cosumnes River	Michigan Bar	56,000	15,000	Once in 100 years
Ione	Dry Creek	Galt	[1]121,000	5,000	Once in 100 years
Pardee	Mokelumne River	Clements	[1]0	10,000	Once in 100 years
Valley Springs	Calaveras River	Jenny Lind	165,000	25,000	Once in 100 years
Melones	Stanislaus River	Knights Ferry	204,000	[4]15,000	Once in 100 years
Don Pedro	Tuolumne River	La Grange	214,000	[4]15,000	Once in 100 years
Exchequer	Merced River	Exchequer	59,000	[4]25,000	Once in 100 years
Friant	San Joaquin River	Friant	75,000	[4]15,000	Once in 100 years
Pine Flat	Kings River	Piedra	80,000	[4]15,000	Once in 100 years
Isabella	Kern River	Bakersfield	67,000	[4]7,500	Once in 100 years

[1] Floods which would cause flows in excess of 10,000 second-feet in the Mokelumne River at Clements would be diverted from the Pardee Reservoir to Dry Creek by the Jackson Creek Spillway and the water stored in Ione Reservoir.
[2] Mean daily flow on day of flood crest. Floods would be controlled to 125,000 second-feet maximum flow exceeded once in 100 years, except when this amount is exceeded by uncontrolled run-off between Kennett Reservoir and Red Bluff. Flows greater than 125,000 second-feet would continue for only a short time.
[3] Folsom reservoir alone would control the flow at Fairoaks to a maximum of 100,000 second-feet exceeded one day in 100 years on an average, by employing 175,000 acre-feet of space in the reservoir for flood control.
[4] Amounts shown are controlled flows during winter floods. During summer floods, the flows would be controlled to amounts not exceeding those shown by combining some reservoir regulation with diversions from the streams for irrigation and underground storage. The control points would not be at those shown with winter floods but would be at points down stream where control is desired to protect lands subject to inundation.

Table 119 sets forth, for various points on the main stream channels, the winter flood flows exceeded once in 100 years on the average, except as noted, without and with reservoir control. The flows in the Sacramento Valley are those that would obtain with the completed Sacramento Flood Control Project, including the protection of Butte Basin. In the San Joaquin Valley, the flows without reservoir control are those that would obtain with levees constructed along the San Joaquin River from a point below Herndon to the delta to form a channel of sufficient width to care for these flows and protect the remaining land now subject to overflow. The flows with reservoir control are those that would obtain with the same channel, but with the flood flows from the larger streams controlled by means of regulation in the major reservoir units of the State Water Plan in this basin to those at the foothill gaging stations shown in Table 118. If protection of the valley lands by means of levees were not effected until after the reservoirs with flood control features were completed, a narrower flood channel along the river could be constructed because of the smaller regulated flows. Under this condition, however, the flows might be slightly larger than those shown in the third column of Table 119, since the reduction of quantities by storage in the narrower channel might be less and the rate of concentration somewhat greater. Flows during summer floods in the San Joaquin River Basin would not exceed those shown in Table 119. Additional details as to flood control in the San Joaquin River Basin are presented in Chapter IX.

Most of the water to be imported from the Sacramento River Basin to the San Joaquin River Basin would be obtained from surplus

TABLE 119

WINTER FLOOD FLOWS IN GREAT CENTRAL VALLEY WITHOUT AND WITH RESERVOIR CONTROL

Stream	Maximum mean daily flow, in second-feet		Number of times flow would be exceeded, on the average
	Without reservoir control	With reservoir control	
Sacramento River at Red Bluff	303,000	[1]187,000	Once in 100 years
Sacramento River at Red Bluff	218,000	[1]125,000	Once in 14 years
Sacramento River and Sutter-Butte By-pass opposite Colusa	370,000	250,000	Once in 100 years
Sacramento River and Sutter-Butte By-pass opposite Colusa	254,000	170,000	Once in 14 years
Sacramento River at Sacramento and Yolo By-pass at Lisbon	670,000	535,000	Once in 100 years
Feather River below confluence with Yuba River	400,000	201,000	Once in 100 years
Feather River below confluence with Bear River	430,000	226,000	Once in 100 years
American River at Fairoaks	185,000	80,000	Once in 250 years
San Joaquin River below confluence with Merced River	70,000	50,000	Once in 100 years
San Joaquin River below confluence with Tuolumne River	103,000	64,000	Once in 100 years
San Joaquin River below confluence with Stanislaus River	133,000	82,000	Once in 100 years
Sacramento and San Joaquin rivers at confluence	780,000	596,000	Once in 100 years

[1] Floods would be controlled to 125,000 second-feet maximum flow exceeded once in 100 years, except when this amount is exceeded by uncontrolled run-off between Kennett Reservoir and Red Bluff. Flows greater than 125,000 second-feet would continue for only a short time.

supplies made available in the Sacramento-San Joaquin Delta channels and would be conveyed to the San Joaquin Valley through the San Joaquin River Pumping System. However, a portion of the imported water supply from the Sacramento River Basin would be furnished by diversion from Folsom Reservoir on the American River to provide a supplemental supply for the area in the San Joaquin River Basin lying east of the delta from the Cosumnes to the Calaveras River (hydrographic divisions Nos. 12 and 13). As a part of the coordinated operation of the American and Cosumnes rivers, it is proposed to furnish by diversion from the Cosumnes River above the Nashville Reservoir a portion of the water requirements for foothill lands in the American River area of the Sacramento River Basin, which can be more economically and practically served in this manner. Sacramento River water from the delta channels, together with return flow and unregulated surplus water from the lower San Joaquin Valley, conveyed through the San Joaquin River Pumping System, would be utilized in part to furnish the water requirements of lands now served by San Joaquin River water and other irrigable lands at present undeveloped in the lower San Joaquin Valley; and in part for the irrigation of the undeveloped irrigable lands to be served on the western slope of the upper San Joaquin Valley with water conveyed thereto through the Mendota-West Side Pumping System.

With the irrigable areas in the lower San Joaquin Valley which would be naturally served by the San Joaquin River furnished a supply by imported Sacramento River water, practically the entire run-off of the San Joaquin River would be regulated at Friant Reservoir and conveyed through the Madera Canal northerly and through the San Joaquin River-Kern County Canal southerly to provide the supplemental supply required for the lands lying on the east side of the upper San Joaquin Valley. The water supplies developed by the major units on the streams tributary to the area on the east side of the upper San Joaquin Valley would be regulated in coordination with supplies from Friant Reservoir, with regulation obtained through the combined use of surface and underground storage. A portion of the water conveyed from the San Joaquin River through the San Joaquin River-Kern County Canal would supply areas now served with Kern River water and make possible the diversion of Kern River water through the Kern River Canal to serve higher lying rim lands along the southern edge of the upper San Joaquin Valley.

The lands on the east side of the lower San Joaquin Valley from the Stanislaus to the Merced rivers, with the exception of a small acreage in the Merced area lying immediately adjacent to the San Joaquin River, would be served by regulated supplies from the main east side tributaries of the San Joaquin River.

Surplus Water in Great Central Valley—Under the proposed plan of operation of the major units of the State Water Plan in the Great Central Valley as just described, there would have been substantial amounts of water, over and above the requirements for the purposes provided for, which would have wasted each year during the eleven-year period 1918–1929 into San Francisco Bay. Most of this waste would have occurred in years of large run-off and in the winter months of other years. Part of the waste water would have spilled from the reservoirs. During the summer months there would have been just sufficient water released from the reservoirs to care for all needs. Part of the waste waters could have been conserved by reservoirs other than the major units of the State Water Plan or by larger major units. Studies showed, however, that these additional regulated waters would not have been necessary during the eleven-year period 1918–1929, for the accomplishments set forth in the foregoing paragraphs.

Although the imported water from the Trinity River would add somewhat to the surplus in years of large run-off in the Sacramento River Basin, more than half of it would be required for the irrigation of lands which could be served by gravity from no other source and a considerable portion of the remainder would be required in the winter months of the drier years for salinity control and navigation. This unit and all of the other selected major units of the State Water Plan would have been required to furnish regulated supplies distributed in accordance with the demand, especially in years of low run-off.

Table 120 shows the net flows into the Sacramento-San Joaquin Delta, the amounts required from this water for all uses in the delta and adjacent uplands, the amounts required for supplemental supplies for irrigation in the San Joaquin Valley and for irrigation and other uses in the San Francisco Bay Basin, the amounts of water which would have flowed past Antioch into Suisun Bay for salinity control, the surplus water which would have reached the delta in addition to that for all requirements, and the total amounts of water which would have flowed into Suisun Bay after all requirements had been satisfied. The amounts shown for net flow into the delta from the San Joaquin Valley include such portions of the unregulated surplus and return waters intercepted by the San Joaquin River Pumping System before reaching the delta, as could have been used in supplying "crop land" rights or new lands in this valley south of the Merced River, obviating the pumping of that portion of this supply from the delta; but do not

TABLE 120

ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY UNDER OPERATION OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY, 1918-1929

Year	Net flow into delta, in acre-feet[1]			Requirements from net flow into delta, in acre-feet					Surplus water above all requirements, in acre-feet	Total flow into Suisun Bay, in acre-feet
	From Sacramento Valley, including area east of delta[2]	From San Joaquin Valley, excluding area east of delta[2]	From both valleys	Total gross allowance for delta and adjacent uplands	Salinity control to lower end of delta	Full irrigation supply for "crop lands" in San Joaquin Valley having rights to water to be diverted at Friant[3]	Irrigation supply for additional new lands in San Joaquin Valley[4]	Supplemental supply for San Francisco Bay Basin		
1918	9,726,000	968,000	10,694,000	1,551,000	2,389,000	896,000	1,570,000	403,000	3,885,000	6,274,000
1919	9,953,000	968,000	10,921,000	1,551,000	2,389,000	896,000	1,570,000	403,000	4,112,000	6,501,000
1920	8,146,000	957,000	9,103,000	1,551,000	2,395,000	896,000	1,570,000	403,000	2,288,000	4,683,000
1921	13,915,000	965,000	14,880,000	1,551,000	2,389,000	896,000	1,570,000	403,000	8,071,000	10,460,000
1922	13,651,000	1,592,000	15,243,000	1,551,000	2,389,000	896,000	1,570,000	403,000	8,434,000	10,823,000
1923	8,693,000	1,050,000	9,743,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,934,000	5,323,000
1924	6,081,000	760,000	6,841,000	1,551,000	2,395,000	583,000	1,020,000	290,000	1,002,000	3,397,000
1925	8,727,000	942,000	9,669,000	1,551,000	2,389,000	896,000	1,570 000	403,000	2,860,000	5,249,000
1926	8,957,000	777,000	9,734,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,925,000	5,314,000
1927	15,361,000	917,000	16,278,000	1,551,000	2,389,000	896,000	1,570,000	403,000	9,469,000	11,858,000
1928	13,339,000	968,000	14,307,000	1,551,000	2,395,000	896,000	1,570,000	403,000	7,498,000	9,893,000
Averages	10,595,000	988,000	11,583,000	1,551,000	2,390,000	868,000	1,520,000	392,000	4,862,000	7,252,000

[1] Includes regulated and unregulated water from reservoirs and return waters. The amounts shown from the San Joaquin Valley include such portions of the unregulated surplus and return flow waters intercepted by the San Joaquin River Pumping System before reaching the delta as could be used in supplying "crop land" rights or additional new lands in this valley south of Merced River, obiviating the pumping of that portion of this supply from the delta; but do not include the portion of such waters intercepted and used in the west side area north of Merced River in Hydrographic Division 7 and in the west side rim lands in Hydrographic Division 7 (a).

[2] Area east of delta includes the watersheds of the Cosumnes, Mokelumne and Calaveras rivers.

[3] "Crop lands" are those areas suitable for growing crops which are now served or probably will be served in the near future by diversions from the San Joaquin River above the mouth of the Merced River under existing rights.

[4] Does not include water requirements of west side area north of Merced River in Hydrographic Division 7, and in west side rim lands in Hydrographic Division 7 (a), amounting to 410,000 acre-feet annually.

include the portion of such waters intercepted and used in the west side area north of Merced River in Hydrographic Division 7 and in the west side rim lands in Hydrographic Division 7(a). Table 136 shows the amounts of such return flow and surplus waters which would be intercepted by the San Joaquin River Pumping System and the areas in which such supplies would be utilized. It also shows the residual flow into the delta after being reduced by the amounts intercepted. However, the return flow and surplus water would have reached the delta under natural conditions and the amounts of such waters intercepted would have to be replaced in the delta by Sacramento River water for irrigation and salinity control uses. Therefore, the water supply to be made available in the delta for exportation to the San Joaquin Valley would be based upon the full amount of the requirements to be met in the areas to be served by the San Joaquin River and Mendota-West Side pumping systems. The amounts shown in the seventh and eighth columns of Table 120 for the San Joaquin Valley are for the full requirements, except those for the west side area north of Merced River in Hydrographic Division 7 and on the west side rim lands in Hydrographic Division 7(a), which were previously deducted from the inflow. "Crop lands" are those lands suitable for growing crops which are now or probably will be served in the near future by diversions, under existing rights, from the San Joaquin River above the mouth of the Merced River.

Table 121 shows the amounts of surplus water in the delta and the total flows into Suisun Bay, by months, for the years of maximum and minimum run-off, and the average for the period 1918–1929. It may be noted that under this method of operation there would have been no surplus in July, August and September of any year. The flow into Suisun Bay shown for these months is that required for salinity control.

TABLE 121

MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY UNDER OPERATION OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY, 1918-1929

Month	Year of maximum run-off, 1927		Year of minimum run-off, 1924		Average for period 1918-1929	
	Surplus water above all requirements in acre-feet	Flow into Suisun Bay, in acre-feet	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet
January	1,054,000	1,257,000	204,000	407,000	722,000	925,00
February	4,043,000	4,227,000	249,000	439,000	1,320,000	1,505,00
March	1,719,000	1,922,000	0	203,000	1,486,000	1,689,00
April	1,029,000	1,225,000	0	196,000	167,000	363,00
May	357,000	560,000	0	203,000	219,000	422,00
June	0	196,000	0	196,000	113,000	309,00
July	0	203,000	0	203,000	0	203,00
August	0	203,000	0	203,000	0	203,00
September	0	196,000	0	196,000	0	196,00
October	32,000	235,000	55,000	258,000	33,000	236,00
November	588,000	784,000	248,000	444,000	328,000	524,00
December	647,000	850,000	246,000	449,000	474,000	677,00
Totals	9,469,000	11,858,000	1,002,000	3,397,000	4,862,000	7,252,00

The data compiled in the foregoing Tables 120 and 121, covering the generally subnormal period of run-off 1918–1929, show that the amounts of water which the plan proposes to export from the Sacramento River Basin to the San Joaquin Valley could have been furnished in each year of this period with an allowable maximum deficiency in supply in the driest year of record of 1924; and that, after providing the amounts proposed for exportation, there still would have been surplus water in each year during the period over and above all the requirements provided for in the proposed ultimate plan of operation and accomplishments of the State Water Plan in the Great Central Valley.

The following portion of Chapter VII is devoted to a presentation of detailed data and information on the operation and accomplishments of the ultimate State Water Plan in the San Joaquin River Basin, with the major units therein operating coordinately with those in the Sacramento River Basin. There are presented: first, the utilizable water supply made available from the major streams as regulated by proposed surface storage reservoirs, underground reservoirs and combinations thereof; second, the utilization of underground reservoirs for storage and pumping of water derived from local tributary run-off and imported supplies brought in by the conveyance units, particularly in the upper San Joaquin Valley; third, the operation and accomplishments of the conveyance units; and, lastly the water supply furnished to meet the water requirements in each hydrographic division of the San Joaquin River Basin, demonstrating the sufficiency of the proposed ultimate plan of development and operation.

Utilizable Water Supply from Major Streams in San Joaquin River Basin.

The utilizable water supply from the major streams, under the ultimate plan of development in the San Joaquin River Basin, varies for different streams and groups of streams and depends upon the water requirements of the area to be served from a particular stream or group of streams, the practicability and economic feasibility of surface storage regulation, the availability of and practicability of utilizing underground storage reservoirs, the necessity in some areas for coordination of local supplies with required importations of supplemental water, and the possible or proposed combinations of underground storage and pumping with surface storage regulation.

Certain surface storage reservoirs on major streams would be of sufficient capacity to regulate the available run-off and provide a surface irrigation supply fully sufficient for the area to be served therefrom. Others would provide only a portion of the regulated supply required and it would be necessary to obtain the remainder of the supply required by underground storage and pumping. On certain streams, full practicable utilization of the run-off could be effected more economically by direct diversions and underground storage regulation and pumping than by surface storage. On some streams, the utilizable supply made available from the fullest practicable regulation by either surface or underground storage or by a combination of both would not be sufficient to meet the water requirements and imported supplies would be required. In such cases, both surface and underground regulation of local supplies would be coordinated with the supplies made available by importation and the regulatory operations and yields of local streams would be governed to some extent by such imported supplies.

In the lower San Joaquin Valley, the proposed storage reservoirs on the Cosumnes, Calaveras and Mokelumne rivers and Dry Creek would be operated coordinately with storage units on the American River in the Sacramento River Basin so that the combined amount of water obtained from these local sources and from the supplies imported from the American River would meet the ultimate water requirements of the irrigable area to be served in hydrographic divisions 12 and 13. The proposed major surface reservoirs on the Stanislaus and Tuolumne rivers would be operated to provide an adequate surface irrigation supply for all irrigable lands to be served in their respective service areas. The requirements of the irrigable lands to be served in the Merced River area are in excess of the surface irrigation supply obtainable from the storage reservoir on Merced River and it is proposed to utilize surplus and waste waters of Merced River through ground water storage and pumping to serve a portion of the area. In addition, the western portion of the Merced area adjacent to the San Joaquin River would be served from the surplus and return flow waters of the lower San Joaquin River and imported Sacramento River water by means of the San Joaquin River Pumping System.

For the area on the east side of the upper San Joaquin Valley from the Chowchilla River to the southern end of the valley, the proposed major reservoirs would be operated in combination with ground water storage and pumping to provide a full supply in all years to the irrigable area to be served under the ultimate plan of development. The utilization of the underground storage in this area is essential to the obtaining of a sufficient water supply to fully meet the ultimate needs. The local sources of water supply utilizable through the proposed major surface storage units and underground storage would be inadequate to meet the demands. The cost of importing water from distant sources would be large. The studies show that, in order to effect the most practicable and economical plan of development, full utilization must be made of the available underground reservoir capacity by means of controlled operations of replenishments and extractions by pumping. Within this entire section on the east side of the upper San Joaquin Valley, the water supplies from the San Joaquin River obtained by regulation through Friant Reservoir would be distributed and used to supplement the available local supplies. Each major reservoir on other streams in this area, in combination with ground water storage and pumping, would be operated coordinately with the imported water supplies from Friant Reservoir to furnish its individual service area a full supply for ultimate needs.

The utilizable yields obtainable from the major streams in the San Joaquin River Basin by surface or underground storage regulation or combinations thereof, with regulatory operations coordinated with imported supplies for areas served by certain streams, are shown in Table 122. The table shows, for each stream, the surface irrigation supply, the additional supply utilizable by ground water storage (for certain streams particularly in the upper San Joaquin Valley), and, finally, the total utilizable supply, which would have been made available each season during the 40-year period 1889–1929. The utilizable yields for the Cosumnes, Mokelumne and Calaveras rivers and Dry Creek are shown each year for the 11-year period 1918–1929 only. The table also shows the name of the surface storage reservoir and its capacity for each of the streams where surface storage is proposed and sets forth the area in which the supply would be utilized.

The seasonal amounts of utilizable water supply shown are those resulting from a month by month study throughout the periods considered. For any one season, they represent the net contribution from the run-off of that season to the utilizable water supply, but do not include supplemental pumping drafts from utilizable supplies previously stored in underground reservoirs.

TABLE 122

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

KERN RIVER

Regulated at Isabella Reservoir, Capacity 338,000 acre-feet. Supply utilized in Hydrographic Division 1

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	606,000	37,800	643,800
1890–91	606,000	0	606,000
1891–92	606,000	38,500	644,500
1892–93	606,000	1,000	607,000
1893–94	606,000	0	606,000
1894–95	606,000	285,300	891,300
1895–96	606,000	14,000	620,000
1896–97	606,000	276,400	882,400
1897–98	493,400	0	493,400
1898–99	330,700	0	330,700
1899–00	319,200	0	319,200
1900–01	585,500	0	585,500
1901–02	606,000	27,300	633,300
1902–03	606,000	0	606,000
1903–04	576,000	0	576,000
1904–05	543,500	0	543,500
1905–06	582,100	669,800	1,251,900
1906–07	606,000	486,000	1,092,000
1907–08	606,000	0	606,000
1908–09	606,000	773,500	1,379,500
1909–10	606,000	232,700	838,700
1910–11	606,000	287,100	893,100
1911–12	606,000	0	606,000
1912–13	420,500	0	420,500
1913–14	584,600	211,600	796,200
1914–15	606,000	84,400	690,400
1915–16	606,000	1,029,600	1,635,600
1916–17	606,000	282,600	888,600
1917–18	606,000	0	606,000
1918–19	606,000	0	606,000
1919–20	606,000	0	606,000
1920–21	531,300	0	531,300
1921–22	583,700	0	583,700
1922–23	606,000	0	606,000
1923–24	323,600	0	323,600
1924–25	463,600	0	463,600
1925–26	340,100	0	340,100
1926–27	584,100	0	584,100
1927–28	521,400	0	521,400
1928–29	328,500	0	328,500
Averages for 40-year period 1889–1929	551,000	119,000	670,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

TULE RIVER

Run-off from main stream regulated at Pleasant Valley Reservoir, Capacity 39,000 acre-feet. Includes yield from run-off of South Fork, without surface storage regulation.
Supply utilized in Hydrographic Division 2

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	103,700	46,200	149,900
1890–91	93,900	0	93,900
1891–92	101,300	20,000	121,300
1892–93	97,400	6,000	103,400
1893–94	93,800	30,100	123,900
1894–95	104,400	102,200	206,600
1895–96	100,800	12,800	113,600
1896–97	99,400	69,200	168,600
1897–98	50,000	0	50,000
1898–99	47,200	0	47,200
1899–00	41,600	0	41,600
1900–01	100,600	46,300	146,900
1901–02	100,500	43,000	143,500
1902–03	100,800	39,700	140,500
1903–04	90,800	0	90,800
1904–05	88,100	0	88,100
1905–06	105,100	333,200	438,300
1906–07	112,000	99,100	211,100
1907–08	97,200	12,300	109,500
1908–09	105,100	257,500	362,600
1909–10	99,100	66,600	165,700
1910–11	100,200	38,000	138,200
1911–12	67,100	0	67,100
1912–13	37,500	0	37,500
1913–14	97,800	60,200	158,000
1914–15	100,900	30,000	130,900
1915–16	105,900	220,700	326,600
1916–17	108,900	68,900	177,800
1917–18	54,500	0	54,500
1918–19	74,300	0	74,300
1919–20	94,200	13,900	108,100
1920–21	88,600	0	88,600
1921–22	100,600	34,100	134,700
1922–23	94,500	5,800	100,300
1923–24	25,000	0	25,000
1924–25	87,300	0	87,300
1925–26	47,700	0	47,700
1926–27	92,500	35,400	127,900
1927–28	47,200	0	47,200
1928–29	53,400	0	53,400
Averages for 40-year period 1889–1929	86,000	42,000	128,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

KAWEAH RIVER

No surface storage regulation. Supply utilized in Hydrographic Division 3

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	318,800	659,800	978,600
1890–91	275,800	233,200	509,000
1891–92	292,900	355,100	648,000
1892–93	287,900	319,100	607,000
1893–94	261,600	137,400	399,000
1894–95	302,300	430,700	733,000
1895–96	255,300	146,200	401,500
1896–97	246,500	224,700	471,200
1897–98	182,600	41,800	224,400
1898–99	228,100	63,400	291,500
1899–00	231,600	79,900	311,500
1900–01	297,000	434,700	731,700
1901–02	239,300	115,800	355,100
1902–03	249,300	154,600	403,900
1903–04	232,200	113,500	345,700
1904–05	251,700	86,000	337,700
1905–06	321,300	623,100	944,400
1906–07	297,600	295,900	593,500
1907–08	220,100	32,500	252,600
1908–09	292,500	468,500	761,000
1909–10	216,200	193,000	409,200
1910–11	281,300	264,700	546,000
1911–12	183,200	24,200	207,400
1912–13	208,600	12,100	220,700
1913–14	265,600	220,400	486,000
1914–15	245,600	123,900	369,500
1915–16	290,700	471,500	762,200
1916–17	273,800	197,700	471,500
1917–18	203,800	25,900	229,700
1918–19	208,000	81,200	289,200
1919–20	232,900	139,200	372,100
1920–21	247,800	113,000	360,800
1921–22	255,400	205,700	461,100
1922–23	247,800	115,700	363,500
1923–24	101,700	0	101,700
1924–25	243,300	82,200	325,500
1925–26	172,500	46,300	218,800
1926–27	251,200	232,000	483,200
1927–28	182,800	20,200	203,000
1928–29	192,100	30,700	222,800
Averages for 40-year period 1889–1929	245,000	190,000	435,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

KINGS RIVER

Regulated at Pine Flat Reservoir, Capacity 400,000 acre-feet. Supply utilized in Hydrographic Division 4

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889-90	1,639,500	1,120,300	2,759,800
1890-91	1,660,000	664,500	2,324,500
1891-92	1,660,000	766,400	2,426,400
1892-93	1,660,000	749,600	2,409,600
1893-94	1,660,000	209,700	1,869,700
1894-95	1,627,700	862,100	2,489,800
1895-96	1,660,000	283,200	1,943,200
1896-97	1,565,400	438,800	2,004,200
1897-98	879,900	0	879,900
1898-99	1,219,800	0	1,219,800
1899-00	1,279,700	0	1,279,700
1900-01	1,596,000	986,200	2,582,200
1901-02	1,548,100	164,400	1,712,500
1902-03	1,491,400	188,000	1,679,400
1903-04	1,502,200	232,500	1,734,700
1904-05	1,421,600	0	1,421,600
1905-06	1,581,000	998,700	2,579,700
1906-07	1,660,000	1,109,400	2,769,400
1907-08	1,181,200	0	1,181,200
1908-09	1,601,900	771,900	2,373,800
1909-10	1,499,200	383,900	1,883,100
1910-11	1,597,500	916,500	2,514,000
1911-12	1,099,200	0	1,099,200
1912-13	940,900	0	940,900
1913-14	1,591,400	776,800	2,368,200
1914-15	1,660,000	264,200	1,924,200
1915-16	1,616,800	973,700	2,590,500
1916-17	1,660,000	345,100	2,005,100
1917-18	1,361,900	0	1,361,900
1918-19	1,199,700	0	1,199,700
1919-20	1,398,100	0	1,398,100
1920-21	1,507,900	15,900	1,523,800
1921-22	1,586,500	423,500	2,010,000
1922-23	1,599,800	0	1,599,800
1923-24	392,000	0	392,000
1924-25	1,285,900	0	1,285,900
1925-26	1,032,900	0	1,032,900
1926-27	1,574,900	398,600	1,973,500
1927-28	969,500	0	969,500
1928-29	847,600	0	847,600
Averages for 40-year period 1889-1929	1,413,000	351,000	1,764,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

SAN JOAQUIN RIVER

Regulated at Friant Reservoir; Utilizable Capacity, 270,000 acre-feet.
Supply utilized in Hydrographic Divisions 1, 2, 3 and 6

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	1,590,900	721,800	2,312,700
1890–91	1,590,900	665,400	2,256,300
1891–92	1,590,900	679,500	2,270,400
1892–93	1,590,900	676,800	2,267,700
1893–94	1,514,900	413,300	1,928,200
1894–95	1,590,900	618,200	2,209,100
1895–96	1,509,000	502,600	2,011,600
1896–97	1,590,900	424,400	2,015,300
1897–98	794,100	218,600	1,012,700
1898–99	1,137,000	119,400	1,256,400
1899–00	1,116,000	218,800	1,334,800
1900–01	1,578,400	593,600	2,172,000
1901–02	1,427,500	334,900	1,762,400
1902–03	1,516,600	217,900	1,734,500
1903–04	1,560,400	162,600	1,723,000
1904–05	1,276,600	319,600	1,596,200
1905–06	1,580,000	549,000	2,129,000
1906–07	1,590,900	772,000	2,362,900
1907–08	978,400	354,100	1,332,500
1908–09	1,576,600	532,300	2,108,900
1909–10	1,516,500	603,800	2,120,300
1910–11	1,590,900	660,900	2,251,800
1911–12	990,600	236,900	1,227,500
1912–13	817,100	62,400	879,500
1913–14	1,565,100	550,200	2,115,300
1914–15	1,590,900	445,900	2,036,800
1915–16	1,590,900	642,400	2,233,300
1916–17	1,582,600	408,700	1,991,300
1917–18	1,377,200	158,900	1,536,100
1918–19	1,120,600	223,400	1,344,000
1919–20	1,253,800	47,100	1,300,900
1920–21	1,328,300	222,300	1,550,600
1921–22	1,561,800	301,000	1,862,800
1922–23	1,403,700	304,100	1,707,800
1923–24	515,600	120,800	636,400
1924–25	1,212,400	59,900	1,272,300
1925–26	1,088,700	137,500	1,226,200
1926–27	1,560,300	313,000	1,873,300
1927–28	996,900	214,200	1,211,100
1928–29	811,700	58,400	870,100
Averages for 40-year period 1889–1929	1,355,000	371,000	1,726,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

Season	FRESNO RIVER Regulated at Windy Gap Reservoir. Capacity, 62,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 6.	CHOWCHILLA RIVER Regulated at Buchanan Reservoir. Capacity, 84,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 6
1889-90	45,700	54,000
1890-91	45,700	54,000
1891-92	45,700	54,000
1892-93	45,700	54,000
1893-94	45,700	54,000
1894-95	45,700	54,000
1895-96	45,700	54,000
1896-97	45,700	54,000
1897-98	45,700	54,000
1898-99	45,700	54,000
1899-00	45,700	54,000
1900-01	45,700	54,000
1901-02	45,700	54,000
1902-03	45,700	54,000
1903-04	45,700	54,000
1904-05	45,700	54,000
1905-06	45,700	54,000
1906-07	45,700	54,000
1907-08	45,700	54,000
1908-09	45,700	54,000
1909-10	45,700	54,000
1910-11	45,700	54,000
1911-12	45,700	54,000
1912-13	45,700	39,700
1913-14	45,700	54,000
1914-15	45,700	54,000
1915-16	45,700	54,000
1916-17	45,700	54,000
1917-18	45,700	54,000
1918-19	45,700	54,000
1919-20	45,700	35,300
1920-21	45,700	54,000
1921-22	45,700	54,000
1922-23	45,700	54,000
1923-24	45,700	54,000
1924-25	45,700	54,000
1925-26	32,800	54,000
1926-27	43,900	54,000
1927-28	45,700	54,000
1928-29	31,700	50,800
Averages for 40-year period 1889-1929	45,000	53,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

MERCED RIVER

Regulated at Exchequer Reservoir, Capacity 279,000 acre-feet.
Supply utilized in Hydrographic Division 8

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889-90	440,000	539,200	979,200
1890-91	440,000	320,900	760,900
1891-92	440,000	352,300	792,300
1892-93	440,000	428,200	868,200
1893-94	440,000	421,500	861,500
1894-95	440,000	491,000	931,000
1895-96	440,000	219,600	659,600
1896-97	440,000	332,500	772,500
1897-98	440,000	48,200	488,200
1898-99	440,000	65,800	505,800
1899-00	440,000	262,400	702,400
1900-01	440,000	457,900	897,900
1901-02	440,000	306,900	746,900
1902-03	440,000	319,500	759,500
1903-04	440,000	333,200	773,200
1904-05	440,000	336,000	776,000
1905-06	440,000	531,600	971,600
1906-07	440,000	533,400	973,400
1907-08	440,000	73,500	513,500
1908-09	440,000	401,600	841,600
1909-10	440,000	281,200	721,200
1910-11	440,000	507,400	947,400
1911-12	440,000	0	440,000
1912-13	384,300	0	384,300
1913-14	422,400	437,100	859,500
1914-15	440,000	385,100	825,100
1915-16	440,000	384,200	824,200
1916-17	440,000	390,000	830,000
1917-18	440,000	296,300	736,300
1918-19	440,000	159,700	599,700
1919-20	440,000	79,600	519,600
1920-21	440,000	373,000	813,000
1921-22	440,000	379,800	819,800
1922-23	440,000	327,100	767,100
1923-24	303,900	0	303,900
1924-25	422,400	232,400	654,800
1925-26	440,000	147,500	587,500
1926-27	440,000	350,200	790,200
1927-28	440,000	257,100	697,100
1928-29	432,600	0	432,600
Averages for 40-year period 1889-1929	434,000	294,000	728,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

Season	TUOLUMNE RIVER Regulated at Don Pedro Reservoir. Capacity 1,000,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 9.	STANISLAUS RIVER Regulated at Melones Reservoir. Capacity 1,090,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 11.
1889-90	1,330,000	905,000
1890-91	1,330,000	905,000
1891-92	1,330,000	905,000
1892-93	1,330,000	905,000
1893-94	1,330,000	905,000
1894-95	1,330,000	905,000
1895-96	1,330,000	905,000
1896-97	1,330,000	905,000
1897-98	1,330,000	905,000
1898-99	1,193,100	760,500
1899-00	1,307,900	825,600
1900-01	1,330,000	900,800
1901-02	1,330,000	905,000
1902-03	1,330,000	905,000
1903-04	1,330,000	905,000
1904-05	1,330,000	905,000
1905-06	1,330,000	905,000
1906-07	1,330,000	905,000
1907-08	1,330,000	905,000
1908-09	1,330,000	905,000
1909-10	1,330,000	905,000
1901-11	1,330,000	905,000
1911-12	1,330,000	905,000
1912-13	1,294,200	905,000
1913-14	1,279,300	905,000
1914-15	1,330,000	905,000
1915-16	1,330,000	905,000
1916-17	1,330,000	905,000
1917-18	1,330,000	905,000
1918-19	1,330,000	905,000
1919-20	1,317,600	905,000
1920-21	1,317,000	889,700
1921-22	1,330,000	905,000
1922-23	1,330,000	905,000
1923-24	1,071,500	905,000
1924-25	1,291,800	873,500
1925-26	1,091,200	721,200
1926-27	1,279,900	872,500
1927-28	1,330,000	905,000
1928-29	1,102,500	667,200
Averages for 40-year period 1889-1929	1,303,000	887,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

Year	CALAVERAS RIVER Regulated at Valley Springs Reservoir. Capacity 325,000 acre-feet. Surface irrigation supply utilized in Hydrographic Divisions 12 and 12A.	MOKELUMNE RIVER Regulated at Pardee Reservoir. Capacity 222,000 acre-feet. Surface irrigation supply utilized in Hydrographic Divisions 12 and 12A[1].
1918	122,900	338,800
1919	103,500	338,800
1920	55,800	216,100
1921	117,500	338,800
1922	122,900	338,800
1923	126,400	338,800
1924	83,100	75,600
1925	95,700	338,800
1926	48,500	231,400
1927	114,100	338,800
1928	89,100	338,800
Averages for 11-year period 1918–1929	98,000	294,000

Year	DRY CREEK Regulated at Ione Reservoir. Capacity 610,000 acre-feet. Surface irrigation supply utilized in Hydrographic Divisions 12 and 12A[2].	COSUMNES RIVER Regulated at Nashville Reservoir. Capacity 281,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 13[3].
1918	184,900	151,800
1919	66,100	151,800
1920	28,700	131,200
1921	234,300	151,800
1922	234,300	199,200
1923	234,300	230,500
1924	88,600	151,800
1925	158,200	151,800
1926	30,000	151,700
1927	220,700	151,800
1928	174,000	169,300
Averages for 11-year period 1918–1929	150,000	163,000

[1] Exclusive of allowance for a draft of 200 million gallons per day by the East Bay Municipal Utility District and spill regulated in Ione Reservoir.

[2] Includes yield from regulation of spill from Pardee Reservoir.

[3] These yields are exclusive of an average annual exportation of 64,000 acre-feet diverted from the Cosumnes River above Nashville Reservoir to the American River Basin.

Operation and Accomplishments of Friant Reservoir—Inasmuch as Friant Reservoir is a key unit for the entire east side of the upper San Joaquin Valley in the ultimate plan of development, it is of importance to present detailed data with respect to its operation and accomplishments. It would be operated primarily to furnish necessary supplies of water to supplement the amounts made available from local sources of supply through the combined utilization of surface and underground storage reservoirs. Tho basis of operation and the amounts of water provided from this reservoir are set forth in the following discussion.

The impaired run-off of the San Joaquin River would be regulated by Friant Reservoir with the proposed utilizable net storage capacity of 270,000 acre-feet. The entire regulated supply obtained therefrom would be conveyed through the Madera and San Joaquin River-Kern County canals to the areas of deficient local supply on the east side of the upper San Joaquin Valley. The total utilizable water supply delivered from the reservoir would be pooled with local water supplies made available from the operation of surface and underground storage units to meet the requirements in the areas served therefrom, both as to total seasonal amounts and rates of delivery.

The amount of water which would be provided for the Madera area is based upon the assumed right of the Madera Irrigation District to acquire San Joaquin River water. It is proposed to furnish seasonally a safe surface irrigation supply of 329,200 acre-feet and additional supplies for ground water storage, with a maximum rate of delivery of 1500 second-feet. Water for ground water storage released for the Madera area would be furnished up to the maximum capacity of the canal from any surplus or waste water from the Friant Reservoir. The desirable monthly distribution of the surface irrigation supply for the Madera area under conditions of ultimate development, in per cent of the total seasonal supply, is as follows:

TABLE 123

DESIRABLE MONTHLY DISTRIBUTION OF SURFACE IRRIGATION SUPPLY FOR SERVICE AREA OF MADERA CANAL UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

In per cent of total seasonal supply

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1.4	0	0	0	1.1	7.0	17.0	23.5	21.6	13.4	7.8	7.2

For the area to be served by the San Joaquin River-Kern County Canal south of the San Joaquin River, it is not proposed to furnish the full amount of required supplemental water as a surface irrigation supply. As presented in Chapter VI, the most desirable and economical development must be based upon the fullest practicable utilization of ground water storage in the areas of deficient water supply. With the available run-off regulated by the proposed Friant Reservoir, the supply obtainable would not be sufficient to meet the demands of a surface irrigation supply in certain months and seasons of the period of run-off considered.

The desirable monthly distribution of a surface irrigation supply for the service area of the San Joaquin River-Kern County Canal under conditions of ultimate development would be as follows:

TABLE 124

DESIRABLE MONTHLY DISTRIBUTION OF SURFACE IRRIGATION SUPPLY FOR SERVICE AREA OF SAN JOAQUIN RIVER-KERN COUNTY CANAL UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

In per cent of total seasonal supply

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0

If the entire supplemental water supply adequate in amount to meet the requirements in the areas served from the San Joaquin River-Kern County Canal were to be furnished during the irrigation season as a surface irrigation supply, the capacity of the canal, as designed most economically, would not be sufficient to deliver the monthly requirements in accord with the above percentages in the months of May, June, July and August. Therefore, under the proposed plan of operation, water would be delivered through the San Joaquin River-Kern County Canal up to its maximum capacity of 3,000 second feet during the months of heavy irrigation demand, March to October, inclusive, whenever that rate of flow would be obtainable. During the remaining four months, November to February, inclusive, the maximum rate of release to the San Joaquin River-Kern County Canal would be 2300 second-feet, which is estimated to be the maximum rate at which water could be absorbed for underground storage in addition to taking care of net use requirements during these months.

Under this proposed plan of operation for Friant Reservoir, the seasonal utilization of the impaired run-off of San Joaquin River under conditions of ultimate development which would have been effected during the 40-year period, 1889–1929, is shown in Table 125. This is a seasonal summary of studies made on a month by month basis. There are shown in this table, for each season during this period, the diversions to the upper San Joaquin Valley through both the Madera and San Joaquin River-Kern County canals for surface irrigation supplies and ground water recharge. There also are shown the evaporation losses in the reservoir and waste past the reservoir and the net accretions or depletions in reservoir storage at the end of each season.

Table 126 shows the diversions to the upper San Joaquin Valley through Madera and San Joaquin River-Kern County canals by months for each season during the 40-year period, 1889–1929. The diversions through the latter canal are graphically shown on Plate LXVI, "Yield from Friant Reservoir for San Joaquin River-Kern County Canal Under Plan of Ultimate Development." The monthly diversions shown on this plate are graphically compared to the desirable monthly surface irrigation demands, predicated upon a supplemental water supply being furnished during the irrigation season.

TABLE 125

SEASONAL UTILIZATION OF THE IMPAIRED RUN-OFF OF THE SAN JOAQUIN RIVER AT FRIANT RESERVOIR UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1889-1929

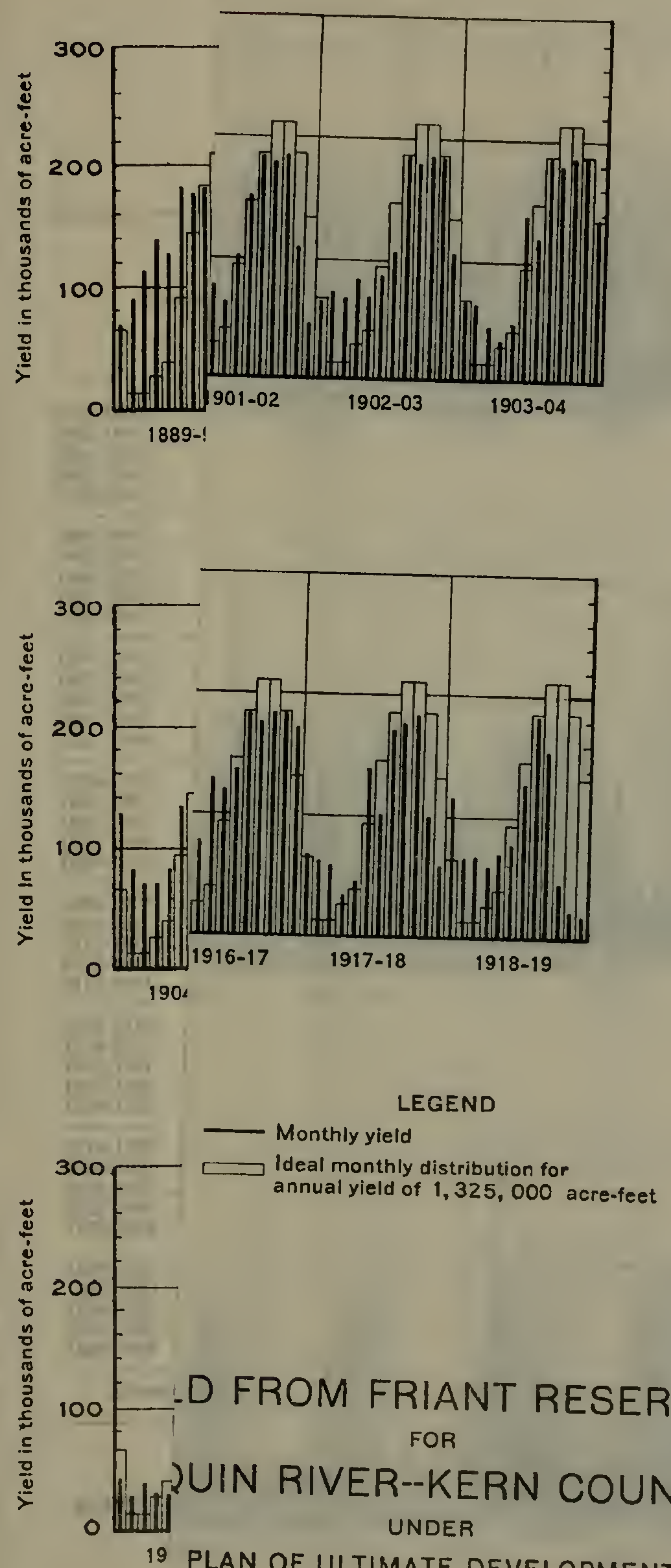
Season	Diversions for upper San Joaquin Valley, in acre-feet							Reservoir evaporation loss, in acre-feet	Waste past reservoir, in acre-feet	Net contribution to reservoir storage, in acre-feet	Total impaired run-off,[1] in acre-feet
	Madera Canal			San Joaquin River-Kern County Canal			Totals				
	Surface supply	Ground water storage	Totals	Surface supply	Ground water storage	Totals					
1889-90	329,200	165,800	495,000	1,261,700	556,000	1,817,700	2,312,700	15,300	2,001,700	+100,900	4,430,600
1890-91	329,200	22,200	351,400	1,261,700	643,200	1,904,900	2,256,300	14,100	186,300	—58,500	2,398,200
1891-92	329,200	81,200	410,400	1,261,700	598,300	1,860,000	2,270,400	14,700	621,700	+11,500	2,918,300
1892-93	329,200	76,800	406,000	1,261,700	600,000	1,861,700	2,267,700	14,600	493,100	—3,500	2,771,900
1893-94	329,200	0	329,200	1,185,700	413,300	1,599,000	1,928,200	10,600	0	—50,400	1,888,400
1894-95	329,200	81,200	410,400	1,261,700	537,000	1,798,700	2,209,100	14,000	459,700	+66,900	2,749,700
1895-96	329,200	18,300	347,500	1,179,800	484,300	1,664,100	2,011,600	12,500	27,600	—38,600	2,013,100
1896-97	329,200	33,200	362,400	1,261,700	391,200	1,652,900	2,015,300	13,400	237,800	—28,300	2,238,200
1897-98	329,200	0	329,200	464,900	218,600	683,500	1,012,700	8,600	0	0	1,021,300
1898-99	329,200	0	329,200	807,800	119,400	927,200	1,256,400	8,600	0	0	1,265,000
1899-00	329,200	0	329,200	786,800	218,800	1,005,600	1,334,800	8,600	0	0	1,343,400
1900-01	329,200	44,700	373,900	1,249,200	548,900	1,798,100	2,172,000	15,300	603,900	+80,800	2,872,000
1901-02	329,200	0	329,200	1,098,300	334,900	1,433,200	1,762,400	10,300	0	—80,800	1,691,900
1902-03	329,200	18,300	347,500	1,187,400	199,600	1,387,000	1,734,500	12,400	16,500	0	1,763,400
1903-04	329,200	18,300	347,500	1,231,200	144,300	1,375,500	1,723,000	12,400	53,700	0	1,789,100
1904-05	329,200	0	329,200	947,400	319,600	1,267,000	1,596,200	8,900	0	0	1,605,100
1905-06	329,200	147,600	476,800	1,250,800	401,400	1,652,200	2,129,000	14,900	1,574,800	+174,500	3,893,200
1906-07	329,200	81,200	410,400	1,261,700	690,800	1,952,500	2,362,900	15,400	643,700	—97,300	2,924,700
1907-08	329,200	0	329,200	649,200	354,100	1,003,300	1,332,500	8,900	0	—77,200	1,264,200
1908-09	329,200	81,200	410,400	1,247,400	451,100	1,698,500	2,108,900	14,400	649,700	+48,400	2,821,400
1909-10	329,200	14,900	344,100	1,187,300	588,900	1,776,200	2,120,300	13,000	3,000	—48,400	2,087,900
1910-11	329,200	153,100	482,300	1,261,700	507,800	1,769,500	2,251,800	15,300	1,196,000	+72,700	3,535,800
1911-12	329,200	0	329,200	661,400	236,900	898,300	1,227,500	9,100	0	—72,700	1,163,900
1912-13	329,200	0	329,200	487,900	62,400	550,300	879,500	8,600	0	0	888,100
1913-14	329,200	104,100	433,300	1,235,900	446,100	1,682,000	2,115,300	15,100	558,800	+80,800	2,770,000

1914-15	329,200	26,700	355,900	1,261,700	419,200	1,680,900	2,036,800	12,700	0	—42,700	2,006,800
1915-16	329,200	114,500	443,700	1,261,700	527,900	1,789,600	2,233,300	15,200	505,100	+6,000	2,759,600
1916-17	329,200	0	329,200	1,253,400	408,700	1,662,100	1,991,300	12,100	0	—44,100	1,959,300
1917-18	329,200	0	329,200	1,048,000	158,900	1,206,900	1,536,100	9,800	0	0	1,545,900
1918-19	329,200	0	329,200	791,400	223,400	1,014,800	1,344,000	9,100	0	0	1,353,100
1919-20	329,200	0	329,200	924,600	47,100	971,700	1,300,900	9,700	0	0	1,310,600
1920-21	329,200	0	329,200	999,100	222,300	1,221,400	1,550,600	9,300	0	0	1,559,900
1921-22	329,200	59,000	388,200	1,232,600	242,000	1,474,600	1,862,800	13,400	368,900	+34,400	2,279,500
1922-23	329,200	0	329,200	1,074,500	304,100	1,378,600	1,707,800	10,100	0	—34,400	1,683,500
1923-24	280,200	0	280,200	235,400	120,800	356,200	636,400	8,600	0	0	645,000
1924-25	329,200	0	329,200	883,200	59,900	943,100	1,272,300	9,000	0	0	1,281,300
1925-26	329,200	0	329,200	759,500	137,500	897,000	1,226,200	9,000	0	0	1,235,200
1926-27	329,200	0	329,200	1,231,100	313,000	1,544,100	1,873,300	12,400	0	0	1,885,700
1927-28	329,200	0	329,200	667,700	214,200	881,900	1,211,100	8,600	0	0	1,219,700
1928-29	329,200	0	329,200	482,500	58,400	540,900	870,100	8,600	0	0	878,700
Average, 1889-1929	328,000	33,500	361,500	1,026,500	338,100	1,364,600	1,726,100	11,700	255,000	0	1,992,800

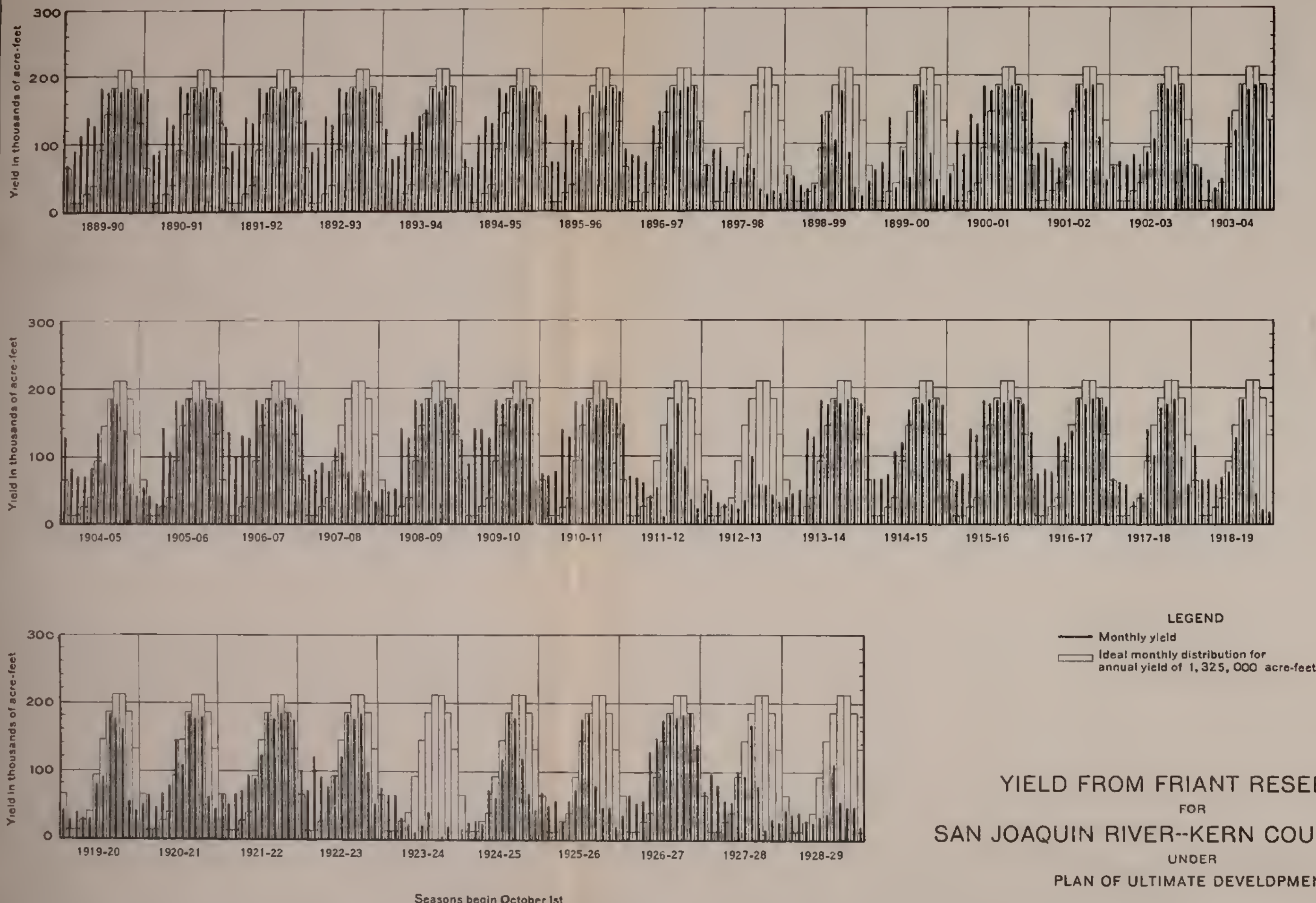
[1] Existing upstream power storage assumed to be operated to obtain the maximum power output.

Under the proposed plan of operation, the Madera area would have received a full surface irrigation supply of 329,200 acre-feet in all seasons during the 40-year period, except 1923–1924, when the supply would have been 280,200 acre-feet. In addition there would have been supplied through the Madera Canal a seasonal average of 33,500 acre-feet during the 40-year period for ground water storage and subsequent utilization by pumping. The ultimate seasonal water requirements of the Madera area (Hydrographic Division No. 6 excluding the Columbia Canal area) aggregate 368,000 acre-feet for a net irrigable area to be served of 184,000 acres. The total requirements for this area are based on a net use of two acre-feet per acre on the assumption that the water would be obtained partly from surface supplies and partly by pumping from the underground reservoir. The primary sources of water supply for this area comprise the San Joaquin, Fresno and Chowchilla rivers. The total safe surface irrigation supply made available from these combined sources aggregates 429,000 acre-feet per season or an amount materially exceeding the estimated water requirements. Therefore, it would appear that the amount of water proposed to be furnished to this area from the San Joaquin River through Friant Reservoir, based upon the assumed right of the Madera Irrigation District to acquire San Joaquin River water, is considerably greater than would be required from this source in addition to the amounts which would be made available from the Fresno and Chowchilla rivers. Moreover, it would appear that the safe surface irrigation supply furnished from the three sources combined would be sufficient to meet the water requirements as estimated without underground storage and pumping. However, extensive pumping from underground is now practiced in this area and it would be necessary to continue utilizing underground storage and pumping under ultimate development in order to fully meet the water demands with a resulting seasonal net use of two acre-feet per acre with the contemplated methods of irrigation distribution and application. In addition, water from underground would be necessary to meet the requirements of a full supply in dry years such as 1924. The total seasonal water supply which would be furnished from the three sources combined, based upon the 40-year period of run-off 1889–1929, would be greater than that required to meet the net use requirements under ultimate development if a practicable and economical utilization were made of the underground reservoir for storage and pumping.*

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to meet the water requirements of the areas on the east side of the upper San Joaquin Valley, during the period of run-off to and including the dry season, 1930–1931, it was found necessary to allocate more of the water supply made available from Friant Reservoir to the areas south of the San Joaquin River and less to the Madera area than that proposed in the plan of operation based on the study of the 40-year period 1889–1929. Under the revised plan of operation presented in Appendix D, the Madera area would be furnished from Friant Reservoir only sufficient water to supplement the amounts available from the Fresno and Chowchilla rivers for meeting the full ultimate net use rquirements under the combined utilization of surface irrigation supplies and underground storage and pumping. This revised plan would require a full practicable utilization of the underground storage reservoir in the Madera area with cyclic underground storage and pumping operations extending throughout the dry period of 1917 to 1931.



-D FROM FRIANT RESERVOIR
FOR
-QUIN RIVER--KERN COUNTY CANAL
UNDER
PLAN OF ULTIMATE DEVELOPMENT



YIELD FROM FRIANT RESERVOIR

FOR

SAN JOAQUIN RIVER--KERN COUNTY CANAL

UNDER

PLAN OF ULTIMATE DEVELDPMENT

TABLE 126

MONTHLY DIVERSIONS FROM SAN JOAQUIN RIVER AT FRIANT RESERVOIR TO UPPER SAN JOAQUIN VALLEY UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1889-1929

Quantities in acre-feet

Season	October		November		December		January		February		March	
	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal
1889-1890	4,600	70,700	0	90,700	0	114,100	0	141,400	3,600	127,700	74,400	184,400
1890-1891	4,600	184,400	0	85,500	0	92,800	0	141,400	3,600	127,700	23,100	184,400
1891-1892	4,600	125,200	0	89,800	0	98,200	0	141,400	3,600	132,300	23,100	184,400
1892-1893	4,600	135,700	0	87,900	0	95,900	0	141,400	3,600	127,700	23,100	184,400
1893-1894	4,600	125,100	0	78,100	0	83,300	0	114,200	3,600	117,800	23,100	141,600
1894-1895	4,600	78,000	0	66,700	0	111,800	0	141,400	3,600	127,700	23,100	184,400
1895-1896	4,600	142,300	0	73,800	0	70,800	0	141,400	3,600	104,600	23,100	157,100
1896-1897	4,600	94,700	0	83,900	0	81,900	0	71,700	3,600	127,700	23,100	149,000
1897-1898	4,600	68,900	0	90,700	0	93,000	0	64,700	3,600	60,200	23,100	48,100
1898-1899	4,600	55,800	0	50,700	0	39,400	0	33,600	3,600	37,700	23,100	140,600
1899-1900	4,600	44,700	0	62,000	0	71,000	0	138,700	3,600	35,600	23,100	88,400
1900-1901	4,600	53,700	0	118,800	0	83,400	0	141,400	3,600	127,700	23,100	184,400
1901-1902	4,600	163,900	0	84,900	0	90,800	0	77,200	3,600	64,900	23,100	101,000
1902-1903	4,600	66,500	0	73,400	0	67,500	0	82,600	3,600	68,500	23,100	86,500
1903-1904	4,600	64,900	0	62,800	0	46,200	0	34,700	3,600	47,200	23,100	138,600
1904-1905	4,600	127,800	0	82,300	0	70,100	0	72,200	3,600	85,500	23,100	133,400
1905-1906	4,600	55,300	0	41,600	0	33,300	0	141,400	3,600	107,500	23,100	184,400
1906-1907	4,600	184,400	0	136,800	0	99,200	0	131,300	3,600	127,700	23,100	184,400
1907-1908	4,600	163,400	0	74,200	0	82,000	0	92,100	3,600	79,500	23,100	114,600
1908-1909	4,600	51,900	0	50,600	0	53,800	0	141,400	3,600	127,700	23,100	184,400
1909-1910	4,600	123,700	0	89,300	0	141,400	0	141,400	3,600	127,700	23,100	184,400
1910-1911	4,600	75,500	0	72,500	0	79,300	0	141,400	3,600	127,700	61,700	184,400
1911-1912	4,600	148,800	0	70,600	0	69,000	0	62,800	3,600	44,600	23,100	55,200
1912-1913	4,600	44,800	0	50,000	0	33,800	0	31,500	3,600	31,500	23,100	24,500
1913-1914	4,600	40,400	0	46,900	0	52,500	0	141,400	3,600	127,700	23,100	184,400
1914-1915	4,600	160,300	0	68,600	0	60,700	0	75,400	3,600	107,700	23,100	121,300
1915-1916	4,600	104,200	0	63,000	0	75,600	0	141,400	3,600	132,300	23,100	184,400
1916-1917	4,600	136,000	0	75,200	0	81,600	0	78,500	3,600	127,700	23,100	121,400
1917-1918	4,600	66,900	0	63,200	0	60,200	0	34,600	3,600	47,200	23,100	138,500
1918-1919	4,600	117,200	0	66,000	0	69,400	0	60,000	3,600	69,700	23,100	77,400
1919-1920	4,600	43,200	0	28,000	0	39,500	0	32,500	3,600	30,500	23,100	82,300
1920-1921	4,600	51,800	0	64,900	0	48,600	0	68,500	3,600	79,700	23,100	146,100
1921-1922	4,600	64,900	0	53,100	0	68,200	0	71,200	3,600	96,200	23,100	87,900
1922-1923	4,600	99,100	0	73,000	0	121,000	0	93,300	3,600	76,500	23,100	92,900
1923-1924	4,600	76,800	0	65,600	0	65,500	0	32,000	3,600	24,200	23,100	10,200
1924-1925	4,600	15,900	0	26,000	0	28,100	0	24,600	3,600	72,000	23,100	61,500
1925-1926	4,600	70,400	0	51,900	0	56,600	0	28,200	3,600	56,600	23,100	74,800
1926-1927	4,600	35,600	0	64,800	0	55,100	0	59,200	3,600	127,700	23,100	150,100
1927-1928	4,600	70,700	0	98,000	0	80,600	0	59,600	3,600	56,000	23,100	101,000
1928-1929	4,600	45,200	0	30,900	0	41,100	0	30,306	3,600	24,700	23,100	34,400
Average, 1889-1929	4,600	91,200	0	70,400	0	72,900	0	89,800	3,600	88,800	25,300	126,900

Season	April		May		June		July		August		September		The season		Total yield
	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	
1889-1890	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	495,000	1,817,700	2,312,700
1890-1891	55,900	178,500	77,300	184,400	89,200	178,500	48,100	184,400	25,800	184,400	23,800	178,500	351,400	1,904,900	2,256,300
1891-1892	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,860,000	2,270,400
1892-1893	55,900	178,500	92,200	184,400	89,200	178,500	87,800	184,400	25,800	184,400	23,800	178,500	406,000	1,861,700	2,267,700
1893-1894	55,900	150,700	77,300	184,400	70,900	178,500	44,200	184,400	25,800	184,400	23,800	56,500	329,200	1,599,000	1,928,200
1894-1895	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,798,700	2,209,100
1895-1896	55,900	77,500	77,300	170,800	80,200	178,500	44,200	184,400	25,800	184,400	23,800	178,500	347,500	1,664,100	2,011,600
1896-1897	55,900	178,500	92,200	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	133,800	362,400	1,652,900	2,015,300
1897-1898	55,900	85,000	77,300	60,800	70,900	31,200	44,200	24,800	25,800	29,700	23,800	26,400	329,200	683,500	1,012,700
1898-1899	55,900	146,600	77,300	104,600	70,900	178,500	44,200	85,300	25,800	34,200	23,800	20,200	329,200	927,200	1,256,400
1899-1900	55,900	50,000	77,300	182,800	70,900	178,500	44,200	85,200	25,800	46,900	23,800	21,800	329,200	1,005,600	1,334,800
1900-1901	67,400	178,500	92,200	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	178,500	373,900	1,798,100	2,172,000
1901-1902	55,900	149,700	77,300	184,400	70,900	178,500	44,200	184,400	25,800	107,300	23,800	46,200	329,200	1,433,200	1,762,400
1902-1903	55,900	106,200	77,300	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	104,100	347,500	1,387,000	1,734,500
1903-1904	55,900	116,600	77,300	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	132,800	347,500	1,375,500	1,723,000
1904-1905	55,900	91,700	77,300	184,400	70,900	178,500	44,200	137,800	25,800	60,000	23,800	43,300	329,200	1,267,000	1,596,200
1905-1906	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	92,200	184,400	23,800	178,500	476,800	1,652,200	2,129,000
1906-1907	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,952,500	2,362,900
1907-1908	55,900	104,200	77,300	76,900	70,900	50,600	44,200	80,500	25,800	50,200	23,800	35,100	329,200	1,003,300	1,332,500
1908-1909	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,698,500	2,108,900
1909-1910	55,900	178,500	92,200	184,400	70,900	178,500	44,200	184,400	25,800	177,700	23,800	64,800	344,100	1,776,200	2,120,300
1910-1911	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	482,300	1,769,500	2,251,800
1911-1912	55,900	12,500	77,300	110,000	70,900	178,500	44,200	84,700	25,800	37,500	23,800	24,100	329,200	898,300	1,227,500
1912-1913	55,900	36,100	77,300	101,300	70,900	59,400	44,200	59,100	25,800	44,300	23,800	34,000	329,200	550,300	879,500
1913-1914	78,800	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	433,300	1,682,000	2,115,300
1914-1915	55,900	167,700	77,300	184,400	70,900	178,500	70,900	184,400	25,800	184,400	23,800	178,500	355,900	1,680,900	2,036,800
1915-1916	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	443,700	1,789,600	2,233,300
1916-1917	55,900	137,500	77,300	184,400	70,900	178,500	44,200	184,400	25,800	184,400	23,800	172,500	329,200	1,662,100	1,991,300
1917-1918	55,900	101,100	77,300	172,100	70,900	178,500	44,200	184,400	25,800	100,200	23,800	60,000	329,200	1,206,900	1,536,100
1918-1919	55,900	120,000	77,300	184,400	70,900	154,100	44,200	45,200	25,800	22,600	23,800	19,800	329,200	1,014,800	1,344,000
1919-1920	55,900	90,900	77,300	184,400	70,900	178,500	44,200	162,100	25,800	58,800	23,800	41,000	329,200	971,700	1,300,900
1920-1921	55,900	110,100	77,300	184,400	70,900	178,500	44,200	181,000	25,800	61,700	23,800	46,100	329,200	1,221,400	1,550,600
1921-1922	55,900	122,900	82,300	184,400	89,200	178,500	79,900	184,400	25,800	184,400	23,800	178,500	388,200	1,474,600	1,862,800
1922-1923	55,900	123,500	77,300	184,400	70,900	178,500	44,200	184,400	25,800	98,500	23,800	53,500	329,200	1,378,600	1,707,800
1923-1924	55,900	21,400	77,300	40,600	27,500	0	44,200	500	25,800	19,400	18,200	0	280,200	356,200	636,400
1924-1925	55,900	118,900	77,300	184,400	70,900	178,500	44,200	117,600	25,800	69,200	23,800	46,400	329,200	943,100	1,272,300
1925-1926	55,900	178,500	77,300	184,400	70,900	79,500	44,200	48,200	25,800	48,100	23,800	19,800	329,200	897,000	1,226,200
1926-1927	55,900	178,500	77,300	184,400	70,900	178,500	44,200	184,400	25,800	184,400	23,800	141,400	329,200	1,544,100	1,873,300
1927-1928	55,900	93,900	77,300	168,000	70,900	80,000	44,200	15,700	25,800	31,100	23,800	27,300	329,200	881,900	1,211,100
1928-1929	55,900	40,000	77,300	112,200	70,900	55,900	44,200	49,500	25,800	50,000	23,800	17,700	329,200	540,900	870,100
Average, 1889-1929	59,200	131,000	82,300	166,200	77,600	155,600	57,700	144,700	27,500	125,500	23,700	101,600	361,500	1,364,600	1,726,100

The areas served under the San Joaquin River-Kern County Canal would have received a surface irrigation supply in accord with the demand averaging 1,026,500 acre-feet per season, but varying in amount considerably for different seasons of the 40-year period. In addition, an average seasonal supply of 338,100 acre-feet for ground water storage and subsequent utilization by pumping would have been made available during the 40-year period. The total supply furnished during the 40-year period would have averaged 361,500 acre-feet for the areas served by the Madera Canal and 1,364,600 acre-feet for the areas served by the San Joaquin River-Kern County Canal, or a total average seasonal supply of 1,726,100 acre-feet.

The allocation of the total supply delivered through the San Joaquin River-Kern County Canal to the individual areas served therefrom is dependent upon the deficiencies between water requirements and local supplies and is further related to the capacity and practicable degree of utilization of the underground reservoirs in each area. The actual allocation was based upon a detailed study of the combined operation of local surface storage and underground storage reservoirs in the individual local areas. After making preliminary trial studies leading up to the final study of the operation of the underground reservoirs as presented hereafter, the allocation of the supplemental water supply furnished from Friant Reservoir, in per cent of the total monthly and seasonal deliveries, to the several hydrographic divisions was made as follows:

Division 1	31 per cent
Division 2	64 per cent
Division 3	5 per cent
Division 4	0 per cent

With this allocation of supplemental water from the San Joaquin River added to the supplies made available from local sources in the individual hydrographic units, the detailed studies presented hereafter show that the water requirements for the areas to be served under the ultimate plan would have been fully met; and that, in addition, water in excess of the net use requirements would have accumulated in underground storage reservoirs over the forty-year period 1889–1929.

Utilization of Underground Reservoirs in San Joaquin River Basin.

The utilization of underground reservoirs for the storage of water and subsequent extraction by pumping is a basic feature of the proposed ultimate plan of development in the San Joaquin River Basin. Such utilization is essential, particularly in the upper San Joaquin Valley, where the ultimate water requirements are materially in excess of the local supplies which can be developed, and for which supplemental water supplies must be imported from areas of surplus supply. Therefore, under the ultimate State Water Plan, it is proposed to utilize the available underground storage capacity in those sections of the basin where practicable, necessary and desirable.

The locations, extent and capacities of underground storage reservoirs in the San Joaquin Valley have been discussed in Chapter VI. The results of a geologic study made to locate these storage reservoirs, to estimate their capacities and determine the practicability of their utilization for the storage and regulation of water supplies in irrigation development are presented in Appendix B of this report, ''Geology and Underground Water Storage Capacity of San Joaquin Valley.'' It has been demonstrated in Chapter IV that, under existing conditions of development in the upper San Joaquin Valley, gross absorptive areas totaling more than 1,600,000 acres are now utilized for the storage and regulation of water supplies serving an aggregate net area of more than 800,000 acres. In the upper San Joaquin Valley the gross absorptive areas total 2,432,000 acres and have aggregate estimated utilizable storage capacities of some 20,000,000 acre-feet. The gross absorptive areas in the lower San Joaquin Valley total 558,000 acres with estimated utilizable aggregate storage capacities of more than 3,000,000 acre-feet. All of these absorptive areas are confined to the eastern slope of the valley, principally to the alluvial cones and flood plains of the major streams. The surface soil and geologic formation on the western slope and in the trough of the valley are of such character that no utilizable underground capacity exists. The total usable capacities of the ground water reservoirs have been set forth for each hydrographic division in Table 100, Chapter VI.

Operation of Underground Reservoirs in Upper San Joaquin Valley.

Within Hydrographic Division 6, considerable underground storage space is now utilized. The capacity available between a depth of 10 feet and the ground water levels of 1929 is estimated as 760,000 acre-feet, and between depths of 10 and 55 feet, as 2,300,000 acre-feet. The underground storage capacity would be utilized to some extent under ultimate development. However, with the water supplies furnished from the San Joaquin, Fresno and Chowchilla rivers providing a safe surface irrigation supply of 429,000 acre-feet per season to the Madera area and with a safe surface irrigation supply of 26,000 acre-feet per season furnished from the San Joaquin River Pumping System for the Columbia Canal area, based upon the regulation of available run-off up to 1929, adequate service to this area would be provided with a very moderate degree of utilization of the underground storage capacity.*

For the remaining portion of the east side of the upper San Joaquin Valley south of the San Joaquin River, the underground reservoirs would be utilized to the fullest practicable extent. The practicable degree of utilization and the results of a practical plan of operation, with the local and imported water supplies which would have been available and with the water requirements fully met each season,

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to meet the water requirements of the areas on the east side of the upper San Joaquin Valley during the period of run-off to and including the dry season 1930–1931, it was found necessary to allocate more of the water supply made available from Friant Reservoir to the areas south of the San Joaquin River and less to the Madera area than that proposed in the plan of operation based on the study of the 40-year period 1889–1929. Under the revised plan of operation presented in Appendix D, the Madera area would be furnished from Friant Reservoir only sufficient water to supplement the amounts available from the Fresno and Chowchilla rivers for meeting the full ultimate net use requirements under the combined utilization of surface irrigation supplies and underground storage and pumping. This revised plan would require a full practicable utilization of the underground storage reservoir in the Madera area with cyclic underground storage and pumping operations extending throughout the dry period of 1917 to 1931.

have been determined by a detailed study for the forty-year period 1889–1929. The study resolved itself into two parts:

1. The determination of monthly "net use" requirements and the maximum capacity of water supply utilization.

2. The determination of amounts of accumulative ground water storage resulting from the utilization of local and imported supplies through the combined means of surface application, ground water draft and replenishment.

Net Use and Maximum Capacity of Water Supply Utilization—The "capacity of water supply utilization" in a particular area is defined as that amount of the total supply made available thereto from local and imported sources which would be utilized in the area for net use requirements and ground water storage. For any particular period, it is the sum of total net use and net contributions to ground water through seepage from artificial conveyance channels, absorption in natural stream channels and spreading areas, and through irrigation applications in excess of net use. As used in this report, the "maximum capacity of water supply utilization" in any specified period for a particular area is the sum of the total net use and the maximum amount of water that could be absorbed for storage in the underground reservoir based upon rates of absorption well within those established by measurements on streams and conveyance channels and upon application losses resulting from usual irrigation practice in fully developed irrigated areas.

Based upon the data presented in Chapters IV and V, the average seasonal net use has been established as 2.0 acre-feet per net irrigable acre for all of the upper San Joaquin Valley. The ideal monthly net use was varied for each division in proportion to its present irrigation demand as influenced by local conditions of climate and existing development. These values expressed in acre-feet per acre are shown in Table 127.

TABLE 127

MONTHLY DISTRIBUTION OF SEASONAL NET USE

In acre-feet per acre

Month	Hydrographic Division			
	1	2	3	4
October	0 10	0.10	0.10	0.10
November	0.06	0.06	0.04	0.02
December	0.06	0.06	0.04	0.02
January	0.08	0.08	0.06	0.04
February	0.08	0.08	0.06	0.06
March	0.16	0.16	0.16	0.14
April	0.22	0.22	0.22	0.22
May	0.24	0.24	0.26	0.28
June	0.28	0.28	0.30	0.32
July	0.28	0.28	0.30	0.32
August	0.24	0.24	0.26	0.28
September	0.20	0.20	0.20	0.20
Totals	2.00	2.00	2.00	2.00

The total amount of water that would be absorbed for storage in underground reservoirs in the several hydrographic divisions of the upper San Joaquin Valley would be made up of, first, the water absorbed by deep percolation from application of irrigation supplies in excess of net use; second, the water absorbed through seepage losses from artificial conveyance channels; and third, the water absorbed from losses in natural stream channels and spreading areas.

The average maximum net application on irrigated lands in absorptive areas in months when excess water would be available has been estimated as exceeding the net use by about 50 per cent from October to March, inclusive, and about 100 per cent from April to September, inclusive, with slight modifications for differing local conditions. These values expressed in acre-feet per acre are shown in Table 128. The amounts of water actually applied in excess of net use

TABLE 128

MONTHLY DISTRIBUTION OF MAXIMUM NET IRRIGATION APPLICATIONS ON ABSORPTIVE AREAS

In acre-feet per acre

Month	Hydrographic Division			
	1	2	3	4
October	0.14	0.14	0.15	0.15
November	0.10	0.10	0.06	0.03
December	0.10	0.10	0.06	0.03
January	0.12	0.12	0.09	0.06
February	0.12	0.12	0.09	0.09
March	0.24	0.24	0.24	0.21
April	0.47	0.47	0.47	0.34
May	0.51	0.51	0.52	0.69
June	0.51	0.51	0.54	0.69
July	0.51	0.51	0.54	0.64
August	0.46	0.46	0.50	0.42
September	0.37	0.37	0.39	0.30

would percolate downward and be stored in the underground rese voirs. In addition to these amounts of water applied for irrigation i excess of net use which are based upon usual irrigation practice, dee percolation losses caused by poor land leveling and wasteful applica tion methods have been estimated at an average of 0.25 acre-foot pe net acre per season.

In estimating the amounts of water absorbed through seepag losses from unlined canals, it has been assumed that the main cana and branch canals would be lined; that the branch canals would delive water to each section of land; and that distribution in each sectio would be made to each forty-acre tract by means of unlined lateral Seepage losses have been calculated at the rate of 1.3 cubic feet pe square foot of wetted perimeter in 24 hours, as determined by actu measurements on canals and ditches on the Kaweah Delta. Maximu monthly and total seasonal seepage losses from the unlined lateral computed on the bases assumed, would amount respectively to 0.06 acr foot and 0.50 acre-foot per net acre of irrigable land in absorptive area These estimated maximum monthly and total seasonal seepage losses fo unlined laterals only, as related to irrigable area, are but 25 per cen of corresponding quantities for an entirely unlined canal system, whic would amount to 0.24 acre-foot per net acre in a maximum month, and 2.0 acre-feet per season, based on the same seepage loss rate of 1.3 cubic feet per square foot in 24 hours.

The foregoing estimated total seasonal maximum capacities of water supply utilization involved in the conveyance and application of irrigation supplies, comprising normal maximum irrigation applications, excess irrigation applications due to rough land and seepage losses from lateral ditches, aggregate 4.40 acre-feet per acre of net irrigable area in each hydrographic division, of which 2 acre-feet per acre would be for net use requirements. The maximum amount of water delivered in any season would be much less than 4.40 acre-feet per acre, because no season of record would yield sufficient water for more than a few months to satisfy the maximum capacities of water supply utilization involved in this total.

The areas of irrigation application in each hydrographic division were divided into absorptive and nonabsorptive lands above and below the location of the San Joaquin River-Kern County Canal, deductions being made for areas supplied by yields of minor streams. The nonabsorptive areas are considered capable of utilizing a net use delivery only, and the absorptive areas a maximum net application delivery. In addition, the percolation losses from unlined laterals and excess application losses due to rough land and wasteful application methods are considered to apply only to absorptive areas. The net areas of these subdivisions follow:

Division	*Acres*
Hydrographic Division 1, exclusive of west side rim lands.	
Net absorptive area, above location of San Joaquin River-Kern County Canal and south of Kern River	247,000
Net absorptive area, below location of canal	128,000
Net nonabsorptive area, below location of canal	154,000
Total net area to be served by water from San Joaquin and Kern rivers	529,000
Hydrographic Division 2, exclusive of west side rim lands.	
Net nonabsorptive area, above location of San Joaquin River-Kern County Canal, to be supplied jointly by Tule River and pumping from canal	111,000
Net nonabsorptive area, below location of canal	196,000
Net absorptive area, below location of canal	178,000
Total net area to be served by water from San Joaquin and Tule rivers	485,000
Hydrographic Division 3	
Net absorptive area	207,000
Net nonabsorptive area	42,000
Total net area to be served by water from San Joaquin and Kaweah rivers	249,000
Hydrographic Division 4	
Net absorptive area	622,000
Net nonabsorptive area adjacent to foothills	104,000
Net nonabsorptive area in Tulare Lake vicinity	104,000
Total net area to be served by Kings River	830,000

In addition to maximum net applications and losses from unlined canals, estimates have been made of the maximum absorptive capacities of the natural stream channels and other existing channels that could be used for absorption of water into the underground reservoirs in each hydrographic division. These maximum absorptive capacities for natural stream channels, sloughs and existing artificial canals were determined by a study of available stream and channel seepage measurements aided by field examinations on certain streams and sloughs and by direct field seepage measurements on others.

In Hydrographic Division 1, the Kern River has an estimated absorptive capacity of 170 second-feet above and 150 second-feet below the location of the San Joaquin River-Kern County Canal; and contributing chiefly to the area below the canal location, the Calloway and Lerdo canals, 250 second-feet, and the East Side Canal, Rim Ditch and upper reach of Kern Island Canal, 100 second-feet. The total absorptive capacity of these channels amounts to about 40,000 acre-feet per month.

In Hydrographic Division 2, the Tule River has an estimated absorptive capacity of 200 second-feet above and 300 second-feet below the location of the San Joaquin River-Kern County Canal. Deer Creek, Old Deer Creek and White River have an estimated total absorptive capacity of 100 second-feet above the canal location. Below the canal location small channels near Strathmore, Old Slough, Dead Horse Slough, Porter Slough, Poplar Ditch, Old Deer Creek, Deer Creek and White River have an estimated total absorptive capacity of 350 second-feet. The total absorptive capacity of these channels amounts to about 57,000 acre-feet per month.

In Hydrographic Division 3, the Kaweah River has an estimated absorptive capacity of 300 second-feet, and the many spreading channels, now in use, have a capacity of 530 second-feet. The total absorptive capacity of these channels amounts to about 50,000 acre-feet per month.

In Hydrographic Division 4, the Kings River channels have an estimated absorptive capacity of 500 second-feet which amounts to about 30,000 acre-feet per month.

Based upon the foregoing estimated maximum capacities of utilization involved in conveyance and application of irrigation supplies and in absorption from stream channels, the maximum monthly capacities of water supply utilization and all factors appertaining thereto are shown for each of the hydrographic divisions 1, 2, 3 and 4 in Tables 129, 130, 131 and 132, respectively. In Tables 129 and 130, "upper area" and "lower area" designate the areas respectively above and below the location of the San Joaquin River-Kern County Canal.

TABLE 129

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 1, EXCLUSIVE OF WEST SIDE RIM LANDS

In acre-feet

Month	Assumed delivery per acre of irrigable land				Upper area	Lower area		Both areas
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net irrigable absorptive area, 247,000 acres	Net irrigable absorptive area, 128,000 acres	Net irrigable nonabsorptive area, 154,000 acres	Total net irrigable area, 529,000 acres
		On absorptive areas			Maximum monthly capacity, including 10,000 acre-feet in river channels	Maximum monthly capacity, including 30,000 acre-feet in river and other spreading channels	Net use delivery	Total maximum monthly capacity
October	0.10	0.14	0.05	0.19	56,900	54,300	15,400	126,600
November	0.06	0.10	0.03	0.13	42,100	46,600	9,200	97,900
December	0.06	0.10	0.03	0.13	42,100	46,700	9,300	98,100
January	0.08	0.12	0.03	0.15	47,100	49,200	12,300	108,600
February	0.08	0.12	0.03	0.15	47,100	49,200	12,300	108,600
March	0.16	0.24	0.06	0.30	84,100	68,400	24,600	177,100
April	0.22	0.47	0.08	0.55	145,800	100,400	33,900	280,100
May	0.24	0.51	0.09	0.60	158,200	106,800	37,000	302,000
June	0.28	0.51	0.09	0.60	158,200	106,800	43,100	308,100
July	0.28	0.51	0.09	0.60	158,200	106,800	43,100	308,100
August	0.24	0.46	0.09	0.55	145,900	100,400	37,000	283,300
September	0.20	0.37	0.08	0.45	121,100	87,600	30,800	239,500

TABLE 130

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 2, EXCLUSIVE OF WEST SIDE RIM LANDS

In acre-feet

Month	Assumed delivery per acre of irrigable land				Upper area	Lower area		Both areas
		Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net irrigable nonabsorptive area, 111,000 acres	Net irrigable nonabsorptive area, 196,000 acres	Net irrigable absorptive area, 178,000 acres	Total net irrigable area, 485,000 acres
	Net use	On absorptive areas			Net use delivery plus 36,000 acre-feet in stream and other spreading channels	Net use delivery	Maximum monthly capacity, including 21,000 acre-feet in stream and other spreading channels	Total maximum monthly capacity
October	0.10	0.14	0.05	0.19	47,100	19,600	54,800	121,500
November	0.06	0.10	0.03	0.13	42,700	11,800	44,100	98,600
December	0.06	0.10	0.03	0.13	42,700	11,800	44,200	98,700
January	0.08	0.12	0.03	0.15	44,900	15,700	47,700	108,300
February	0.08	0.12	0.03	0.15	44,900	15,700	47,700	108,300
March	0.16	0.24	0.06	0.30	53,700	31,300	74,400	159,400
April	0.22	0.47	0.08	0.55	60,400	43,100	118,900	222,400
May	0.24	0.51	0.09	0.60	62,600	47,000	127,800	237,400
June	0.28	0.51	0.09	0.60	67,100	54,900	127,800	249,800
July	0.28	0.51	0.09	0.60	67,100	54,900	127,800	249,800
August	0.24	0.46	0.09	0.55	62,600	47,000	118,900	228,500
September	0.20	0.37	0.08	0.45	58,200	39,200	101,100	198,500

TABLE 131

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 3

In acre-feet

Month	Assumed delivery per acre of irrigable land				Net irrigable nonabsorptive area, 42,000 acres	Net irrigable absorptive area, 207,000 acres	Total net irrigable area, 249,000 acres
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net use delivery	Maximum monthly capacity including 50,000 acre-feet in river and other spreading channels	Total maximum monthly capacity
		On absorptive areas					
October	0.10	0.15	0.05	0.20	4,200	91,400	95,600
November	0.04	0.06	0.03	0.09	1,700	68,600	70,300
December	0.04	0.06	0.03	0.09	1,700	68,600	70,300
January	0.06	0.09	0.03	0.12	2,500	74,800	77,300
February	0.06	0.09	0.03	0.12	2,500	74,900	77,400
March	0.16	0.24	0.06	0.30	6,700	112,100	118,800
April	0.22	0.47	0.08	0.55	9,300	163,900	173,200
May	0.26	0.52	0.09	0.61	10,900	176,300	187,200
June	0.30	0.54	0.09	0.63	12,600	180,400	193,000
July	0.30	0.54	0.09	0.63	12,600	180,400	193,000
August	0.26	0.50	0.09	0.59	10,900	172,100	183,000
September	0.20	0.39	0.08	0.47	8,400	147,300	155,700

TABLE 132

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 4

In acre-feet

Month	Assumed delivery per acre of irrigable land				Net irrigable nonabsorptive area, 208,000 acres	Net irrigable absorptive area, 622,000 acres	Total net irrigable area, 830,000 acres
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net use delivery	Maximum monthly capacity including 30,000 acre-feet in river channels	Total maximum monthly capacity
		On absorptive areas					
October	0.10	0.15	0.05	0.20	21,000	154,000	175,000
November	0.02	0.03	0.03	0.06	4,000	68,000	72,000
December	0.02	0.03	0.03	0.06	4,000	68,000	72,000
January	0.04	0.06	0.03	0.09	8,000	86,000	94,000
February	0.06	0.09	0.03	0.12	13,000	104,000	117,000
March	0.14	0.21	0.06	0.27	29,000	198,000	227,000
April	0.22	0.34	0.08	0.42	46,000	291,000	337,000
May	0.28	0.69	0.09	0.78	58,000	515,000	573,000
June	0.32	0.69	0.09	0.78	67,000	515,000	582,000
July	0.32	0.64	0.09	0.73	66,000	485,000	551,000
August	0.28	0.42	0.09	0.51	58,000	347,000	405,000
September	0.20	0.30	0.08	0.38	42,000	266,000	308,000

Results of Underground Reservoir Operation—Based upon the amounts of utilizable water supply of the major streams and the maximum capacities of water supply utilization as previously presented, a detailed study month by month during the forty-year period 1889–1929 was made of the operation of the underground reservoirs in each hydrographic division of the upper San Joaquin Valley south of the San Joaquin River. The monthly utilizable water supplies for each hydrographic division comprise the combined amounts made available from local major streams and the supplemental water supplies furnished from the San Joaquin River. The amounts of available run-off in any month which were in excess of the maximum capacity of water supply utilization were considered as waste water and not a part of the utilizable water supply of particular hydrographic divisions. The monthly amounts of utilizable water supply were compared with the net use requirements in each hydrographic division. The amount required for net use was deducted from the utilizable supply delivered and the water in excess of net use, if any, was considered as a contribution to ground water storage. If the water supply delivered in any month was less than net use, the deficiency between supply and net use was considered to be the required draft from ground water storage. In this manner, the net accretions to and extractions from the underground reservoirs in each hydrographic division were determined month by month for the forty-year period 1889–1929. The areas assumed to be furnished by water supplies from minor streams in certain of the hydrographic divisions were excluded from this analysis, both as to water supply and water requirements.

The results of this detailed month by month study of the operation of underground reservoirs are set forth in Table 133, and graphically depicted on Plate LXVII, "Operation of Underground Reservoirs in Upper San Joaquin Valley, Under Plan of Ultimate Development, South of San Joaquin River." Table 133 shows the net seasonal accumulative amounts of water remaining in storage in underground reservoirs at the conclusion of each season's operations of ground water recharge and extraction, in each hydrographic division during the forty-year period 1889–1929. The difference between the amounts shown for any two successive seasons represents the net contribution to or draft from the underground reservoir. The table also shows the amounts of water for each season which would have been available from the run-off in excess of the maximum capacities of water supply utilization and considered as waste water not utilizable in particular hydrographic divisions. It may be noted that the total amount of non-utilizable excess water supplies in all four divisions of the upper San Joaquin Valley included in this study is somewhat greater than the net accumulative amount of water remaining in storage in the underground reservoirs at the end of the forty-year period considered. Plate LXVII is based upon the data tabulated in Table 133.

The study of accumulated ground water storage shows that the utilizable water supplies made available for hydrographic divisions 1 to 4, inclusive, in the upper San Joaquin Valley would have been sufficient to fully meet the water requirements of the areas to be served under the ultimate development and in addition to provide considerable

TABLE 133

WATER SUPPLY REMAINING IN STORAGE AT END OF EACH SEASON IN UNDERGROUND RESERVOIRS OF UPPER SAN JOAQUIN VALLEY SOUTH OF SAN JOAQUIN RIVER UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1889-1929

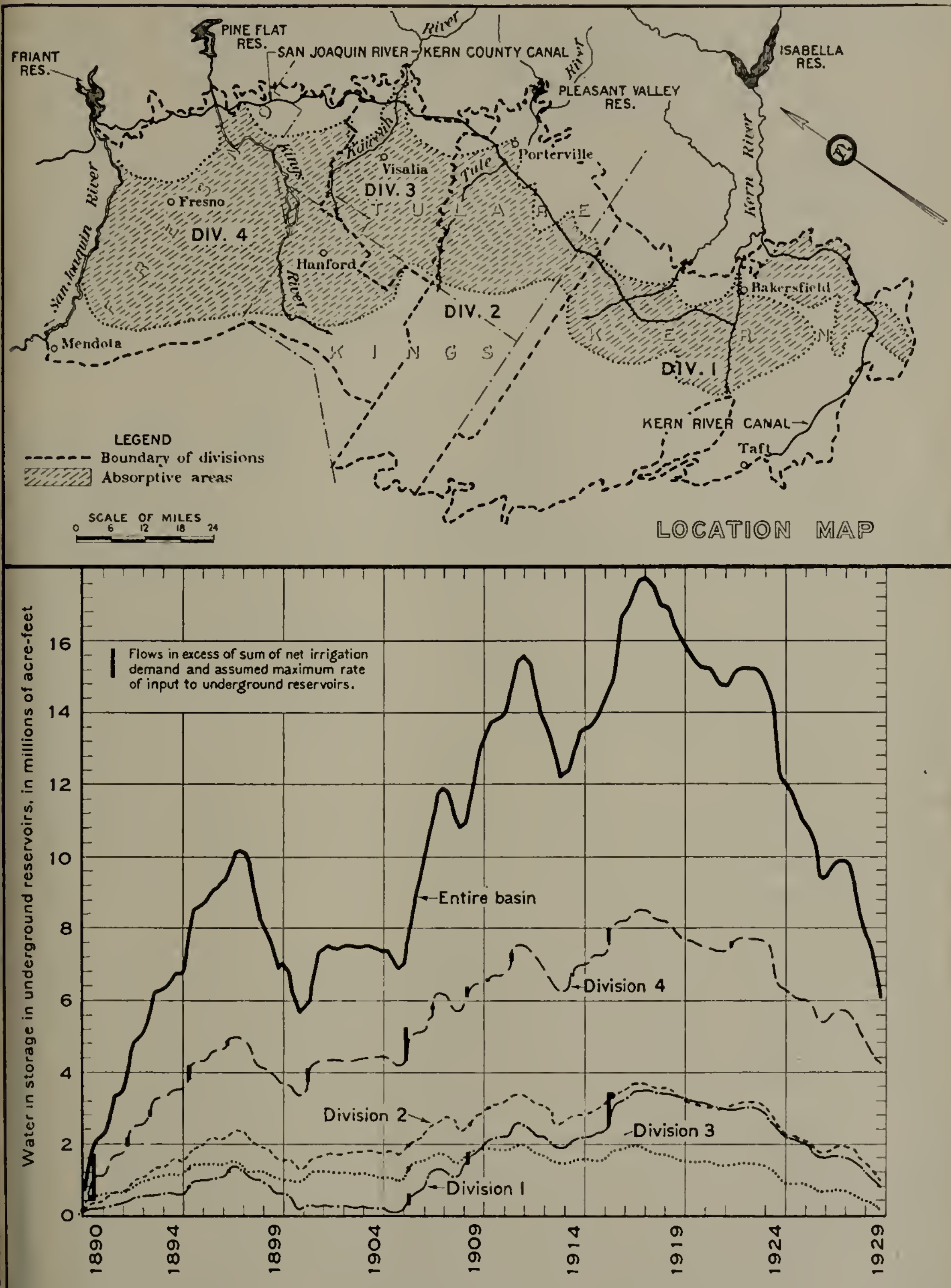
In acre-feet

Season	Hydrographic Division				Total
	1	2	3	4	
1889-90	149,300	343,100	540,900	1,100,900	2,134,200
1890-91	287,800	686,000	647,100	1,766,500	3,387,400
1891-92	448,100	1,027,700	890,100	2,534,000	4,899,900
1892-93	574,200	1,352,600	1,092,100	3,284,700	6,303,600
1893-94	617,900	1,529,900	1,073,000	3,495,500	6,716,300
1894-95	988,300	1,917,600	1,393,400	4,326,400	8,625,700
1895-96	1,066,100	2,126,200	1,380,100	4,610,700	9,183,100
1896-97	1,365,300	2,382,600	1,435,900	4,956,000	10,139,800
1897-98	1,011,600	1,900,000	1,196,500	4,177,000	8,285,100
1898-99	571,600	1,570,600	1,036,300	3,737,900	6,916,400
1899-00	144,500	1,285,800	900,100	3,358,700	5,689,100
1900-01	229,400	1,613,400	1,223,700	4,282,000	7,348,500
1901-02	248,900	1,704,100	1,152,500	4,335,600	7,441,100
1902-03	226,900	1,762,300	1,127,700	4,356,100	7,473,000
1903-04	171,300	1,763,300	1,044,200	4,431,900	7,410,700
1904-05	49,500	1,692,300	947,300	4,194,600	6,883,700
1905-06	643,100	2,140,100	1,480,200	5,115,400	9,378,800
1906-07	1,282,400	2,630,700	1,673,300	6,225,900	11,812,300
1907-08	1,141,400	2,412,300	1,478,100	5,748,200	10,780,000
1908-09	1,856,100	2,819,700	1,832,000	6,463,100	12,970,900
1909-10	2,187,400	3,127,500	1,832,000	6,687,300	13,834,200
1910-11	2,571,100	3,428,100	1,968,500	7,542,400	15,510,100
1911-12	2,212,100	3,100,100	1,722,800	6,982,700	14,017,700
1912-13	1,909,300	2,519,800	1,473,000	6,264,700	12,166,800
1913-14	2,168,900	2,784,200	1,545,100	6,974,000	13,472,200
1914-15	2,322,400	3,020,800	1,500,600	7,239,300	14,083,100
1915-16	3,188,800	3,439,400	1,854,300	8,170,900	16,653,400
1916-17	3,534,700	3,710,900	1,910,900	8,517,100	17,673,600
1917-18	3,456,800	3,567,800	1,702,900	8,220,100	16,947,600
1918-19	3,319,400	3,321,600	1,544,800	7,760,900	15,946,700
1919-20	3,168,600	3,081,600	1,467,500	7,500,100	15,217,800
1920-21	3,020,500	2,981,900	1,391,400	7,365,000	14,758,800
1921-22	3,003,300	3,089,300	1,428,200	7,716,100	15,236,900
1922-23	2,978,600	3,102,900	1,362,600	7,657,000	15,101,100
1923-24	2,354,600	2,385,900	984,100	6,390,100	12,114,700
1924-25	2,052 600	2,106,800	858,700	6,017,100	11,035,200
1925-26	1,612,800	1,758,600	624,300	5,391,100	9,386,800
1926-27	1,617,600	1,904,700	686,700	5,705,700	9,914,700
1927-28	1,354,400	1,546,300	435,800	5,016,300	8,352,800
1928-29	792,600	975,900	187,700	4,205,000	6,161,200

Water in Excess of the Maximum Monthly Utilizable Yields. Not Considered as Part of the Available Supply for Net Use or Ground Water Storage

Season	Hydrographic Division				Total
	1	2	3	4	
1889-90			152,000	1,284.500	1,436,50
1890-91				1,400	1,40
1891-92				252,600	252,60
1892-93				176,900	176,90
1894-95	20,500		4,500	408,200	433,20
1896-97	37,600			110,000	147,60
1900-01				377,800	377,80
1905-06	345,900	77,800	140,100	965,800	1,529,60
1906-07				115,900	115,90
1908-09	292,000	72,200	32,900	298,000	695,10
1909-10		24,600		10,600	35,20
1910-11				166,200	166,20
1913-14				18,000	18,00
1915-16	1,007,300	83,200		341,800	1,432,30
1921-22				124,200	124,20
Totals	1,703,300	257,800	329,500	4,651,900	6,942,50

PLATE LXVII



OPERATION OF UNDERGROUND RESERVOIRS
IN
UPPER SAN JOAQUIN VALLEY
UNDER PLAN OF ULTIMATE DEVELOPMENT
SOUTH OF SAN JOAQUIN RIVER
1889-1929

amounts of water to build up the underground storage. In each hydrographic division, substantial amounts of water would have remained in storage in the underground reservoirs at the end of the forty-year period considered, the net accumulation in all four divisions combined amounting to over 6,000,000 acre-feet after meeting the full water requirements of the area. Assuming an empty underground reservoir at the beginning of the season of 1889–1890, the storage on hand under conditions of ultimate development would have mounted from zero to 10,000,000 acre-feet by 1897. From 1897 to 1900 it would have been drawn down to 6,000,000 acre-feet, to mount almost continuously to 15,000,000 in 1911. From 1911 to 1913 it would have decreased to 12,000,000, to increase again to nearly 18,000,000 in 1917. From 1917 to the end of the period in the fall of 1929, the decrease of storage on hand would have been almost continuous to 6,000,000 acre-feet.

The distribution of the portion of the water supply made available through ground water utilization in each hydrographic division might be somewhat nonuniform with respect to the degree of its accessibility to meet the requirements over the entire area of a particular division. However, it is considered that local pumping and conveyance facilities would be provided to control and distribute the supply so that all lands to be served in each division would receive ample water. No plans have been prepared for such local pumping and distribution facilities as a part of the ultimate State Water Plan. The plan as formulated provides the required water supply for each hydrographic division as a whole, leaving the detailed plans of local distribution to later consideration when necessary. However, sufficient investigations have been made in each area to demonstrate that the water supplies furnished under the plan of operation proposed could be distributed by practicable and feasible methods to meet the requirements of all lands to be served in each hydrographic division.

The available underground capacity in each of the hydrographic divisions and in the entire area, as heretofore presented in Table 100 in Chapter VI, would have been sufficient to provide for the maximum storage regulation required, amounting to about 18,000,000 acre-feet in the entire area. The maximum underground storage capacity that would have been required at any time during the forty-year period is equal to the maximum amount of accumulated ground water storage shown in Table 133. If it were assumed that the utilizable water supply furnished on the average during the forty-year period had only been sufficient to meet the full water requirements and there had been no net accumulation of stored water in the underground reservoirs at the end of the forty-year period, the capacity of underground storage required would have been considerably less than the capacity required for complete regulation and conservation of the entire utilizable water supply provided under the plan. The required underground storage capacities and the corresponding maximum ground water fluctuations, for underground storage regulation of the utilizable water supplies provided under the plan and for regulation of an average water supply equal to water requirements only, are shown in Table 134.

The required underground storage capacities shown in Table 134 for conservation and regulation of the entire utilizable water supply are of about the same magnitude as the utilizable undergound storage

TABLE 134

REQUIRED STORAGE CAPACITY AND MAXIMUM GROUND WATER FLUCTUATION FOR UNDERGROUND STORAGE REGULATION OF UTILIZABLE WATER SUPPLIES IN UPPER SAN JOAQUIN VALLEY SOUTH OF SAN JOAQUIN RIVER UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Hydrographic division	Required underground storage in acre-feet		Gross absorptive area, in acres	Assumed drainage factor, in per cent	Maximum ground water fluctuation below a depth of 10 feet below ground surface. in feet	
	For conservation and regulation of entire utilizable water supply	With average 40-year water supply equal to water requirements			For conservation and regulation or entire utilizable water supply	With average 40-year water supply equal to water requirements
1[2]	3,535,000	3,000,000	525,000	[1]15	47	40
2[2]	3 711,000	3,000,000	322,000	15	77	62
3	1,911,000	1,850,000	308,000	15	42	40
4	8 517,000	5,500,000	996,000	15	57	37
Totals	17,674,000	13,350,000	2,151,000	15	[3]55	[3]42

[1] Except for area north of the seventh parallel in Hydrographic Division 1 where a drainage factor of 12½ per cent was used.
[2] Exclusive of West Side Rim Lands.
[3] Average for entire absorptive area considered.

capacities shown in Table 100 between a depth of 10 feet below ground surface and the assumed economic limit of pumping lift. The capacities required for conservation and regulation of a water supply sufficient only on the average to meet the water requirements are considerably less than these utilizable underground storage capacities. It should be noted, however, that the drainage factors used are conservative, inasmuch as a considerably larger drainage factor was found in many of the principal absorptive areas as shown by the studies presented in Chapter IV. In other words, the required underground storage capacity could probably be obtained within a considerably smaller range of ground water fluctuation than that shown in the table based upon the assumed drainage factor. It is safe to conclude that the required underground storage regulation could have been provided with the water supplies made available, well within the limits of economic pumping lift in all areas.

The large amount of cyclic storage required for the regulation and seasonal distribution of local and imported waters in the upper San Joaquin Valley under conditions of ultimate development can be obtained only by utilization of ground water reservoirs. Possible surface reservoirs would provide only a fraction of the required capacity. Evaporation losses from surface reservoirs utilized for cyclic storage are very great while in underground reservoirs these losses are a minimum. The only feasible method of adequate conservation of water supply produced in wet cycles for use in dry cycles, in this area, consists of the utilization of the large available underground storage space. This utilization would require the installation of ample pumping capacity and the lowering of the water planes in dry cycles.

The results of the detailed study of the operation of underground reservoirs within the area on the east side of the upper San Joaquin

Valley south of the San Joaquin River demonstrate that the proposed plan of service for the ultimate development of this area is adequate. By means of the combined regulation afforded by the proposed surface storage reservoirs and by underground storage and pumping, the study shows that a water supply would have been provided during the forty-year period 1889–1929 more than sufficient to meet the ultimate water requirements of the areas to be served; and that, in addition, water in excess of the net use requirements would have been available for storage in the underground reservoirs, with a substantial net amount of storage accumulated at the end of the forty-year period. The proposed plan of development and operation is the only one which is practicable and economical of accomplishment to meet the demands of this section of the basin. Its dependability is demonstrated by the detailed studies presented.

Operation of Underground Reservoirs in Lower San Joaquin Valley.

Along the eastern slope of the lower San Joaquin Valley, there is available for utilization about 3,000,000 acre-feet of underground capacity with a gross absorptive area of 558,000 acres. However, the utilizable water supplies which would have been available with the proposed major surface storage units for ultimate development during the forty-year period 1889–1929 would have provided an adequate surface irrigation supply for the area to be served, without the use of underground storage and pumping, except in Hydrographic Division 8, where underground storage was utilized to a limited extent.* Under present conditions of development with generally plentiful water supplies, liberal irrigation applications on the lands result in relatively high ground water levels. As a result, the chief problem with respect to ground water is now one of drainage. Ground water levels are being controlled in some areas by use of wells and pumping plants. By utilizing pumped water to meet the peak demands of the irrigation season in these areas, effective use could be made of the underground storage capacity and a more uniform draft upon surface reservoirs could be made. This method of operation would have advantages on a system where hydroelectric power is generated.

In Hydrographic Division 8, it is proposed to utilize the underground reservoir for storage and pumping to supply a portion of water requirements for the area to be served therein. The present constructed Exchequer Reservoir of 279,000 acre-feet capacity on the Merced River would regulate the supply for the major portion of the area to be served with Merced River water but it would not provide a full surface irrigation supply. By means of underground storage and pumping, an average seasonal supply of 294,000 acre-feet from reservoir spill would have been made available for utilization during the forty-year period 1889–1929, in addition to the safe surface irrigation yield of 440,000 acre-feet per season from the reservoir. The total

*Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to provide the required water supplies with the available run-off from 1929 to 1931, including the dry season, 1930–1931, the studies presented in Appendix D show that it would be necessary to utilize the available underground storage in several additional areas in the lower San Joaquin Valley.

utilizable water supply from combined regulation by surface and underground storage is adequate to meet the water requirements for the portion of the area to be served by Merced River water in this hydrographic division.

Operation and Accomplishments of Conveyance Units in San Joaquin River Basin.

The chief function of the proposed conveyance units of the ultimate State Water Plan in the San Joaquin River Basin is the conveyance and distribution of surplus Sacramento River Basin water to the areas of deficient local water supply in the San Joaquin Valley. These units, described in detail in Chapter VI and shown on Plate XXVI, provide in effect a continuous conveyance system for carrying water from the Sacramento River to the southerly end of the San Joaquin Valley. However, in accord with the proposed plan of development found to be most practicable and economical, no physical connection is provided between the San Joaquin River Pumping System and the Madera and San Joaquin River-Kern County canals but the equivalent to a physical connection is effected by the substitution of Sacramento River water at Mendota for San Joaquin River water which would be diverted at Friant Reservoir through the Madera and San Joaquin River-Kern County canals. By means of this exchange of supplies, a saving of about 300 feet in pumping lift is effected as compared to a plan wherein Sacramento River water would be directly conveyed and lifted to the levels of the Madera and San Joaquin River-Kern County canals for serving the easterly slope of the upper San Joaquin Valley. A similar exchange of water for the purpose of saving pumping lift would be made on the Kern River where supplies brought in through the San Joaquin River-Kern County Canal would be substituted for Kern River water which in turn would be diverted through the Kern River Canal to higher lying rim lands along the southerly extremity of the San Joaquin Valley.

Madera and San Joaquin River-Kern County Canals—The operation and accomplishments of the Madera and San Joaquin River-Kern County canals have been set forth in detail previously in this chapter in connection with the presentation of the operation and accomplishments of Friant Reservoir and of the utilization and operation of the underground reservoirs in the upper San Joaquin Valley. These canals would be operated to deliver water from Friant Reservoir on the San Joaquin River to supplement the supplies made available from local sources on the easterly slope of the upper San Joaquin Valley. The total water supply delivered through these canals during the forty-year period would have averaged 361,500 acre-feet per season for the area served by the Madera Canal and 1,364,600 acre-feet for the areas served by the San Joaquin River-Kern County Canal, or a total average seasonal supply of 1,726,100 acre-feet. With the supplemental supplies delivered by these canals from San Joaquin River added to the supplies made available from local sources, the water requirements for the areas to be served under the ultimate plan of development on the easterly slope of the upper San Joaquin Valley would have been fully met; and, in addition, water in excess of the net use requirements would have accumulated in the underground storage reservoirs over the forty-year period 1889–1929.

San Joaquin River and Mendota-West Side Pumping Systems—The San Joaquin River and Mendota-West Side pumping systems would be operated primarily to furnish the required water supply for the areas to be served on the westerly slope of both the upper and lower San Joaquin Valley. The source of water supply would be chiefly surplus Sacramento River Basin water conveyed through these systems by successive pumping lifts from the delta to the southerly terminus of the Mendota-West Side Pumping System near Elk Hills. An additional source of supply would be the return flows from irrigated lands in the lower San Joaquin Valley and unregulated surplus water of the San Joaquin River and its east side tributaries. In the portion of the pumping system utilizing the San Joaquin River channel are located five dams, from Dam No. 1 below the mouth of the Stanislaus River to Dam No. 5 below the mouth of the Merced River. These dams, at varying elevations, would intercept the return flows from irrigated lands and unregulated surplus waters tributary to the channel above them. The dam at Mendota would also intercept return flow from the tributary irrigated areas above and surplus flows of the San Joaquin River passing Friant Dam. Those portions of the return flows and surplus waters available during the period of pumping would be intercepted and combined with Sacramento River water pumped from the Sacramento-San Joaquin Delta channels to supply the lands to be served by the San Joaquin River and Mendota-West Side pumping systems. The result would be lower capital and annual costs than could be obtained by pumping the entire supply from the Sacramento-San Joaquin Delta channels with a lift from approximateley sea level. However, although a portion of the supply for these lands would be furnished from the intercepted surplus and return waters of the lower San Joaquin Valley, any water so intercepted would have reached the delta under natural conditions and must therefore be replaced with Sacramento River water to provide for irrigation and salinity control uses in the delta and the water requirements of adjacent delta uplands. Therefore, considering necessary replacement of intercepted return flow and surplus waters from the lower San Joaquin Valley by Sacramento River water, the water provided in the delta from the Sacramento River for use in the San Joaquin Valley necessarily would be sufficient in amount to furnish the water requirements for all lands to be served therein by the San Joaquin River and Mendota-West Side pumping systems.

The areas and water requirements to be served under the ultimate State Water Plan in the San Joaquin River Basin by water conveyed through the San Joaquin River and Mendota-West Side pumping systems are shown in Table 135, by hydrographic divisions.

The water requirements shown in Table 135 would be furnished partly from return and surplus waters from the San Joaquin River Basin but for the most part from Sacramento River water. The return flow and surplus water intercepted by the San Joaquin River Pumping System would be utilized on certain lands in the area to be served b

TABLE 135

AREAS AND WATER REQUIREMENTS OF LANDS TO BE SERVED BY SAN JOAQUIN RIVER AND MENDOTA-WEST SIDE PUMPING SYSTEMS UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Area served	Hydrographic division	Net irrigable area, in acres	Seasonal water requirements (gross allowance), in acre-feet
West side area north of Merced River	7	62,000	124,000
West side rim lands north of Mendota	7a	143,000	286,000
Areas south of Merced River, now served from San Joaquin River	7	203,000	670,000
	8	69,000	226,000
Columbia Canal area	6	13,000	26,000
Mendota to Kettleman Hills	5	260,000	520,000
Mendota to Kettleman Hills	5B	221,000	442,000
West side rim lands, upper San Joaquin Valley	2e	74,000	148,000
West side rim lands, upper San Joaquin Valley	1f	217,000	434,000
Totals		1.262,000	2,876,000

the pumping system, so allocated as to save as much pumping of Sacramento River water as possible. The west side area at present receiving a pumped supply derived from the east side tributaries of the San Joaquin River would be allotted a full supply from this source under the State Plan for ultimate development. The west side rim lands in Hydrographic Division 7a would also be served from the return flow and surplus water of the lower San Joaquin Valley. Lands south of Merced River now served from the San Joaquin River in hydrographic divisions 7 and 8 would receive a partial supply from this source supplemented by Sacramento River water. In certain months in every season, there would be more than sufficient water from return flows and surplus waters to meet the demands of this area and in other months a considerable portion of the required supply would be imported from the Sacramento River Basin. An adequate supply with a maximum deficiency of less than 35 per cent in an exceptionally dry season would be received. The amounts of surplus and return waters in any month in excess of the demands of these lands in the lower San Joaquin Valley would be available for areas on the west side of upper San Joaquin Valley south of Mendota. However, the major portion of the required supply for this latter area would be imported from the Sacramento River Basin, resulting in an adequate supply with a maximum deficiency of less than 35 per cent in an exceptionally dry season. Return and surplus waters not utilizable for irrigation demands, including those occurring in the winter months especially, would flow into the Sacramento-San Joaquin Delta.

The utilizable water supply provided from return and surplus waters in the San Joaquin River Basin and from importations from the Sacramento River Basin for delivery through the San Joaquin River and Mendota-West Side pumping systems, to satisfy the water requirements as set forth in Table 135, is shown for each season of the twelve-year period 1917–1929 in Table 136. The amounts from each source for each hydrographic division and in total for the entire area served are set forth. There also are shown the estimated amounts and sources of return and surplus flows in the San Joaquin River Basin, and, lastly, the residual flow into the Sacramento-San Joaquin Delta after deduction of the amounts of return and surplus water intercepted and utilized.

Based upon the data presented in Table 136 showing the areas served and the amounts and sources of the water supply conveyed through the San Joaquin River Pumping System, the seasonal amounts of water which would have been pumped through each pumping plant of the system are shown for the twelve-year period 1917–1929 in Table 137. The data set forth in this table form the basis for the estimated cost of electric energy for pumping presented in the estimates of annual cost of this pumping system in Chapter VI.

TABLE 137

WATER PUMPED THROUGH SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Season	Seasonal quantities, in acre-feet					
	Plant 1	Plant 2	Plants 3 and 4	Plant 5	Plants 6, 7 and 8	Plants 9 and 10
1917–18	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1918–19	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1919–20	1,901,800	1.918,800	2,247,100	2,212,300	2,526,000	2,303,800
1920–21	1,897,400	1 915.700	2,247,100	2,212,300	2,526.000	2,303,800
1921–22	1,515,100	1,532,100	1,821,200	1,793,300	2,187,500	2,004,700
1922–23	1,814,000	1,831,800	2,165,200	2,130,400	2,526,000	2,303,800
1923–24	1,257,900	1,274,200	1,548,600	1,513,800	1,835,600	1,681,900
1924–25	1,907,600	1,929,200	2,247,100	2,212,300	2,495,900	2,274,600
1925–26	1,999,900	2,007,200	2,287,000	2,252,200	2,526,000	2,303,800
1926–27	1 933,200	1,951,300	2,267,400	2,232,600	2,526,000	2,303,800
1927–28	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1928–29	2,027,700	2,033,900	2,321,900	2,287,100	2,526,000	2,303,800
Average, 1917–29	1,828,000	1,845,000	2,158,000	2,124,000	2,438,000	2,225,000
Installed capacity, in second-feet	7,000	7,000	7,500	7,500	8,000	6,500

The area to be served by the Mendota-West Side Pumping System comprises hydrographic divisions 5, 5B, 2c, and 1f, embracing 772,000 acres of good lands on the westerly slope of the upper San Joaquin Valley extending from Mendota to Elk Hills. The seasonal water requirements for these lands aggregate 1,544,000 acre-feet. The loca streams tributary to this area have an erratic or flashy flow and ar not considered as furnishing an appreciable supply. The underlyin formations are so heavily impregnated with the chemical constituent of the adjacent west side mountain range that shallow ground waters even if made available through the generous application of surfac irrigation, would be rendered unfit for irrigation use. Therefore, suc underground reservoir capacity as may exist within these hydrographi divisions is not considered as available for utilization. The tota water requirements for the entire area would therefore be furnished a a surface irrigation supply. The required supply, delivered throug the Mendota-West Side Pumping System, would be obtained fro return flow and surplus water of the lower San Joaquin Valley an from Sacramento River water, delivered to Mendota by means of th San Joaquin River Pumping System. A safe surface irrigation suppl of the amount required would be furnished from these sources with maximum deficiency of 35 per cent in exceptionally dry seasons. Th

UMPING SYSTEMS

	…le rim lands, Divisions 1f and 2e					Seasonal return flow, in acre-feet		
	From Sacramento River Basin	Total	Total from Sacramento River Basin	Total from San Joaquin River Basin	Seasonal return flow and unregulated surplus from east side tributaries of San Joaquin River, in acre-feet	From west side area north of Merced River, Division 7	From San Joaquin River areas south of Merced River Divisions 7 and 8	Residual flow into Sacramento-San Joaquin Delta, in acre-feet
19	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
19	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
19	507,900	582,000	1,731,700	1,144,000	1,034,200	18,600	313,500	222,300
1	508,100	582,000	1,725,700	1,150,000	1,036,100	18,600	313,500	218,200
19	414,300	582,000	1,369,100	1,506,600	1,291,200	18,600	*682,400	485,600
1	507,400	582,000	1,641,700	1,234,000	1,124,200	18,600	313,500	222,300
1	315,600	402,600	1,090,300	1,025,500	970,900	18,600	258,300	222,300
1	508,300	571,800	1,726,100	1,118,700	988,200	18,600	272,100	160,200
1	508,000	582,000	1,860,200	1,015,500	905,700	18,600	313,500	222,300
19	521,100	582,000	1,760,500	1,115,200	936,000	18,600	313,500	152,900
19	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1	508,000	582,000	1,891,200	984,500	874,700	18,600	313,500	222,300
	485,100	566,200	1,663,900	1,145,900	1,024,000	18,600	*336,200	232,900

and, lastly, the residual flow into the Sacramento-San Joaquin Delta after deduction of the amounts of return and surplus water intercepted and utilized.

Based upon the data presented in Table 136 showing the areas served and the amounts and sources of the water supply conveyed through the San Joaquin River Pumping System, the seasonal amounts of water which would have been pumped through each pumping plant of the system are shown for the twelve-year period 1917–1929 in Table 137. The data set forth in this table form the basis for the estimated cost of electric energy for pumping presented in the estimates of annual cost of this pumping system in Chapter VI.

TABLE 137

WATER PUMPED THROUGH SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Season	Seasonal quantities, in acre-feet					
	Plant 1	Plant 2	Plants 3 and 4	Plant 5	Plants 6, 7 and 8	Plants 9 and 10
1917–18	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1918–19	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1919–20	1,901,800	1.918,800	2,247,100	2,212,300	2,526,000	2,303.800
1920–21	1.897,400	1 915.700	2,247,100	2,212,300	2,526.000	2,303,800
1921–22	1,515,100	1,532,100	1,821,200	1,793,300	2,187.500	2,004,700
1922–23	1,814,000	1,831,800	2,165,200	2,130,400	2,526,000	2,303,800
1923–24	1,257,900	1,274,200	1,548,600	1,513,800	1,835,600	1,681,900
1924–25	1,907,600	1,929,200	2,247,100	2,212,300	2,495,900	2,274,600
1925–26	1,999,900	2,007,200	2,287,000	2,252,200	2,526,000	2,303,800
1926–27	1 933,200	1,951,300	2,267,400	2,232,600	2,526,000	2,303,800
1927–28	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1928–29	2,027,700	2,033,900	2,321,900	2.287,100	2,526,000	2,303,800
Average, 1917–29	1,828,000	1,845,000	2,158,000	2,124,000	2,438,000	2,225,000
Installed capacity, in second-feet	7,000	7,000	7,500	7,500	8,000	6,500

The area to be served by the Mendota-West Side Pumping System comprises hydrographic divisions 5, 5B, 2e, and 1f, embracing 772,000 acres of good lands on the westerly slope of the upper San Joaquin Valley extending from Mendota to Elk Hills. The seasonal water requirements for these lands aggregate 1,544,000 acre-feet. The local streams tributary to this area have an erratic or flashy flow and are not considered as furnishing an appreciable supply. The underlying formations are so heavily impregnated with the chemical constituents of the adjacent west side mountain range that shallow ground waters even if made available through the generous application of surface irrigation, would be rendered unfit for irrigation use. Therefore, such underground reservoir capacity as may exist within these hydrographic divisions is not considered as available for utilization. The total water requirements for the entire area would therefore be furnished as a surface irrigation supply. The required supply, delivered through the Mendota-West Side Pumping System, would be obtained from return flow and surplus water of the lower San Joaquin Valley and from Sacramento River water, delivered to Mendota by means of the San Joaquin River Pumping System. A safe surface irrigation supply of the amount required would be furnished from these sources with a maximum deficiency of 35 per cent in exceptionally dry seasons. Th

TABLE 136

UTILIZABLE WATER SUPPLY FOR LANDS SERVED BY SAN JOAQUIN RIVER AND MENDOTA-WEST SIDE PUMPING SYSTEMS UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1917-1929

Season	Seasonal supply in acre-feet (gross allowance)																			Seasonal return flow and unregulated surplus from east side tributaries of San Joaquin River, in acre-feet	Seasonal return flow, in acre-feet		Residual flow into Sacramento-San Joaquin Delta, in acre-feet
	Lands north of Mendota								Lands south of Mendota									Total from Sacramento River Basin	Total from San Joaquin River Basin		From west side area north of Merced River, Division 7	From San Joaquin River areas south of Merced River Divisions 7 and 8	
	West side area north of Merced River, Division 7	West side rim lands, Division 7a	San Joaquin River areas south of Merced River, Divisions 7 and 8			Columbia Canal area, Division 6			Mendota to Kettleman Hills below elevation 350, Division 5			Mendota to Kettleman Hills above elevation 350, Division 5B			West side rim lands, Divisions 1f and 2e								
	From San Joaquin River Basin	From San Joaquin River Basin	From San Joaquin River Basin	From Sacramento River Basin	Total	From San Joaquin River Basin	From Sacramento River Basin	Total	From San Joaquin River Basin	From Sacramento River Basin	Total	From San Joaquin River Basin	From Sacramento River Basin	Total	From San Joaquin River Basin	From Sacramento River Basin	Total						
1917-18	124,000	286,000	540,800	354,900	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1918-19	124,000	286,000	540,800	354,900	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1919-20	124,000	286,000	534,000	361,700	895,700	3,300	22,700	26,000	66,300	453,700	520,000	56,300	385,700	442,000	74,100	507,900	582,000	1,731,700	1,144,000	1,034,200	18,600	313,500	222,300
1920-21	124,000	286,000	540,800	354,900	895,700	3,200	22,800	26,000	66,000	454,000	520,000	56,100	385,900	442,000	73,900	508,100	582,000	1,725,700	1,150,000	1,036,100	18,600	313,500	218,200
1921-22	124,000	286,000	644,100	251,600	895,700	7,500	18,500	26,000	149,900	370,100	520,000	127,400	314,600	442,000	167,700	414,300	582,000	1,369,100	1,506,600	1,291,200	18,600	*682,400	485,600
1922-23	124,000	286,000	622,700	273,000	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,641,700	1,234,000	1,124,200	18,600	313,500	222,300
1923-24	124,000	286,000	380,800	239,000	619,800	3,900	14,100	18,000	77,700	282,000	359,700	66,100	239,600	305,700	87,000	315,600	402,600	1,090,300	1,025,500	970,000	18,600	258,300	222,300
1924-25	124,000	286,000	537,400	354,900	892,300	2,800	22,800	25,600	56,800	454,100	510,900	48,200	386,000	434,200	63,500	508,300	571,800	1,726,100	1,118,700	988,200	18,600	272,100	160,200
1925-26	124,000	286,000	406,000	489,700	805,700	3,200	22,800	26,000	66,100	453,900	520,000	56,200	385,800	442,000	74,000	508,000	582,000	1,860,200	1,015,500	905,700	18,600	313,500	222,300
1926-27	124,000	286,000	540,800	354,900	895,700	2,700	23,300	26,000	54,500	465,500	520,000	46,300	395,700	442,000	60,900	521,100	582,000	1,760,500	1,115,200	936,000	18,600	313,500	152,900
1927-28	124,000	286,000	540,800	354,900	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1928-29	124,000	286,000	375,000	520,700	895,700	3,200	22,800	26,000	66,100	453,900	520,000	56,200	385,800	442,000	74,000	508,000	582,000	1,891,200	984,500	874,700	18,600	313,500	222,300
Mean, 1917-1929	124,000	286,000	517,000	355,400	872,400	3,600	21,700	25,300	72,500	433,400	505,900	61,700	368,300	430,000	81,100	485,100	566,200	1,663,900	1,145,900	1,024,000	18,600	*336,200	232,900

* Includes waste from Friant Reservoir.

TABLE 138

SUMMARY OF WATER REQUIREMENTS AND WATER SUPPLY FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS

Hydrographic Division	Description of area served	Net irrigable area served, in acres	Seasonal water requirements, in acre-feet			Sources of water supply			Seasonal utilizable water supply, in acre-feet					
									From San Joaquin River Basin				From Sacramento River Basin[5]	Totals
			Gross allowance	Net allowance	Net use	Local	Return flow and unregulated surplus	Imported	San Joaquin River at Friant	Local streams	Return flow and unregulated surplus	Totals		
1a	North of Poso Creek, to be served by pumping lifts above the San Joaquin River-Kern County Canal	17,000	34,000	34,000	34,000			San Joaquin River	[1]36,000			36,000		36,000
1b	Between Kern River and Poso Creek, within pumping lifts of 200 feet above Beardsley and Lerdo canals	36,000	72,000	72,000	72,000	Kern River and Poso Creek				[1]74,000		74,000		74,000
1d	South of Kern River within pumping lifts of 350 feet above Kern River Canal	58,000	116,000	116,000	116,000	Kern River and minor streams				[1]119,000		119,000		119,000
1f	West side rim lands above elevation 250 feet, to be served by Mendota-West Side Pumping System	217,000	434,000	434,000	434,000		Lower San Joaquin Valley	Sacramento River			[2] [4]72,000	72,000	[2]362,000	434,000
1	Valley lands, including municipal areas, and excluding areas in 1a, 1b, 1d and 1f	463,000	926,000	926,000	926,000	Kern River and minor streams		San Joaquin River	[1]387,000	[1]567,000		954,000		954,000
	Totals, Hydrographic Division 1	791,000	1,582,000	1,582,000	1,582,000				423 000	760,000	72,000	1,255,000	362,000	1,617,000
2a	East side rim lands within pumping lifts of 250 feet above San Joaquin River-Kern County Canal	78,000	156,000	156,000	156,000			San Joaquin River	[1]159,000			159,000		159,000
2b	East side rim lands to be served jointly by pumping lifts from San Joaquin River-Kern County Canal and gravity diversions from Tule River	31,000	62,000	62,000	02,000	Tule River		San Joaquin River	[1]23,000	[1]39,000		62,000		62,000
2c	Land served entirely by gravity diversions from Tule River	10,000	20,000	20,000	20,000	Tule River				[1]20,000		20,000		20,000
2d	Lands served by pumping lifts from Tule River diversion conduits	13,000	26,000	26,000	26,000	Tule River				[1]27,000		27,000		27,000
2e	West side rim lands above elevation 250 feet, to be served by Mendota-West Side Pumping System	74,000	148,000	148,000	148,000		Lower San Joaquin Valley	Sacramento River			[2] [4]25,000	25,000	[2]123,000	148,000
2	Valley lands, excluding areas in 2a, 2b, 2c, 2d and 2e	360,000	720,000	720,000	720,000	Tule River and Deer Creek		San Joaquin River	[1]692,000	[1]56,000		748,000		748,000
	Totals, Hydrographic Division 2	566,000	1,132,000	1,132,000	1,132,000				874,000	142,000	25,000	1,041,000	123,000	1,164,000
3	Valley lands, including municipal areas	270,000	540,000	540,000	540,000	Kaweah River and minor streams		San Joaquin River	[1]68,000	[1]477,000		545,000		545,000
4	Valley lands, including municipal areas	830,000	1,660,000	1,660,000	1,660,000	Kings River				[1]1,764,000		1,764,000		1,764.000
5	Kettleman Hills to Mendota, below elevation 350 feet	260,000	520,000	520,000	520,000		Lower San Joaquin Valley	Sacramento River			[2] [4]87,000	87,000	[2]433,000	520,000
5B	Kettleman Hills to Mendota, above elevation 350 feet	221,000	442,000	442,000	442,000		Lower San Joaquin Valley	Sacramento River			[2] [4]74,000	74,000	[2]368,000	442,000
	Totals, hydrographic divisions 5 and 5B	481,000	962,000	962,000	962,000						161,000	161,000	801,000	962,000
6	Valley lands, exclusive of Columbia Canal area	184,000	368.000	368,000	368,000	Chowchilla, Fresno and San Joaquin rivers			[1]361,000	[3]100,000		461,000		461,000
6	Columbia Canal area	13,000	26,000	26,000	26,000		Lower San Joaquin Valley	Sacramento River			[2] [4]4,000	4,000	[2]22,000	26,000
	Totals, Hydrographic Division 6	197,000	394,000	394,000	394,000				361,000	100,000	4,000	465,000	22,000	487,000

(1) Average for 40-year period 1889-1929, made available by combination of surface storage and underground storage and pumping.
(2) Safe surface irrigation supply with a maximum allowable deficiency not exceeding 35 per cent in an exceptionally dry season.
(3) Average for 11-year period 1918-1929, the combination of local and imported waters providing a safe surface irrigation supply with a maximum allowable deficiency not exceeding 35 per cent in an exceptionally dry year.
(4) To be replaced in delta by Sacramento River Basin water.
(5) Does not include water from Sacramento River Basin which would be required to replace in the delta the return flow and unregulated surplus water from the lower San Joaquin Valley intercepted and utilized before reaching the delta.
(6) Exclusive of 64,000 acre-feet, exported to foothill area in American River Basin and diverted from Cosumnes River above Nashville Reservoir.

capacity, pumping lift, and seasonal amount of water pumped by each pumping plant of the Mendota-West Side Pumping System are shown in Table 113 in Chapter VI.

The location of the Mendota-West Side Pumping System is in general along the lower edge of the lands to be served. The utilization of most of the water supplies delivered through this conduit would require the construction and operation of local pumping projects having total lifts varying from 250 to 500 feet. These projects would be similar in plan to existing pumping projects on the westerly slope of the lower San Joaquin Valley north of Merced River. The weighted average lift of all local pumping projects would be about 220 feet.

Summary of Operation and Accomplishments.

Based upon the foregoing presentation of the operation and accomplishments of the physical units of the ultimate State Water Plan in San Joaquin River Basin, there is summarized in Table 138 the sources and amounts of the water supplies that would be furnished to meet the water requirements of the areas to be served in each hydrographic division of the basin. For each hydrographic division and special subdivisions thereof, the table shows:

First—The net irrigable area to be served in acres.

Second—The seasonal water requirements in acre-feet, including the amounts for gross allowance, net allowance and net use.

Third—The sources of water supply, including local major and minor streams, surplus and return flows available for reuse and imported supplies from outside the particular hydrographic divisions.

Fourth—The total seasonal utilizable water supply in acre-feet made available from each source of supply.

The basic data with respect to the areas to be served and the water requirements are presented in Chapter V. The sources and amounts of utilizable water supply and the methods of obtaining these supplies through the operation of the major physical units of surface storage, underground storage and conveyance have been presented in detail previously in this chapter. In general, the water supply required for the areas to be served would be obtained from local sources up to the fullest practicable development of the amounts available, regulated by means of both surface and underground storage, where available.

On the east side of the upper San Joaquin Valley including hydrographic divisions 1, 2, 3 and 6, the local water supplies capable of being developed would be insufficient to meet the requirements and the supplemental water supplies required would be furnished from the San Joaquin River. In the entire area on the east side of the upper San Joaquin Valley, comprising hydrographic divisions 1, 2, 3, 4 and 6, the water provided from both local and outside sources would be furnished as far as possible as a surface irrigation supply, but a considerable portion of the supply required would be obtained through ground water storage and pumping. The utilization of underground storage in this portion of the upper San Joaquin Valley is most essential. The bulk of the utilizable water supply would be obtained from the major streams, the amounts of which are set forth in Table 122. The minor streams in general would furnish but a small amount. In Division No. 1, Poso and Caliente creeks and other minor streams would furnish a mean seasonal supply, based on the forty-year period 1889–1929, sufficient to serve about 45,000 acres. In Division No. 2, the minor streams Deer Creek and White River would furnish a mean seasona supply of about 14,000 acre-feet for the same period. In Divisio No. 3, the minor streams Limekiln and Yokohl creeks would furnish a mean seasonal supply of about 42,000 acre-feet for the same period.

In the area on the east side of the lower San Joaquin Valley embraced within hydrographic divisions 8, 8A, 9, 9A, 11 and 11A adequate water supplies would be obtained for practically the entir area to be served from the local sources of supply comprising Merced Tuolumne and Stanislaus rivers. One exception to this would be in Hydrographic Division 8 where a portion of the area adjacent to th San Joaquin River would be served by return flow and surplus wate and Sacramento River water diverted from the San Joaquin Rive Pumping System. The total utilizable supply which could be mad available from Merced River would not be sufficient for the entire are to be served in hydrographic divisions 8 and 8A and hence the servic of a portion of the area from the San Joaquin River Pumping Syste is required. Most of this area in Hydrographic Division 8 that woul be served from the San Joaquin River Pumping System under ultimat development is now served from return flows and crop land waters c the San Joaquin River and hence the ultimate plan of service would l similar to the present. A portion of the utilizable supplies for Hydro graphic Division No. 8 would be obtained from ground water storag and pumping of surplus Merced River water, but the bulk of the wate would be furnished as a surface irrigation supply. The supplies fo hydrographic divisions 9, 9A, 11 and 11A would be surface irrigatio supplies entirely, based upon the utilizable supply for the forty-yea period 1889–1929.

In the remaining portion of the east side of the lower San Joaqui Valley, comprising hydrographic divisions 12, 12A, 13 and 13A, th water supplies would be obtained chiefly from the local streams bu would be supplemented partly by supplies obtained from the America River in the Sacramento River Basin. Based upon the utilizable su plies that would have been available during the forty-year peri 1889–1929, ground water storage utilization is not contemplated these divisions, and an adequate supply would be furnished from t local streams and the American River for surface irrigation.

The major portion of the irrigable area in Hydrographic Divisi 10 now receives its supply through local pumping projects diverti Sacramento and San Joaquin river waters from delta channels. Und conditions of ultimate development the entire area to be served in th division would be supplied in a like manner for the most part wi Sacramento River water.

For the areas to be served on the westerly slope of both the upp and lower San Joaquin valleys, the water supply would be obtain chiefly by importation from the Sacramento River Basin. However substantial amount of the required supply would be obtained from t

Imported	Seasonal utilizable water supply, in acre-feet					
	From San Joaquin River Basin				From Sacramento River Basin[5]	Totals
	San Joaquin River at Friant	Local streams	Return flow and unregulated surplus	Totals		
Joaquin River---	(1)36,000	------------	------------	36,000	------------	36,000
------------	------------	(1)74,000	------------	74,000	------------	74,000
------------	------------	(1)119,000	------------	119,000	------------	119,000
mento River---	------------	------------	(2) (4)72,000	72,000	(2)362,000	434,000
Joaquin River---	(1)387,000	(1)567,000	------------	954,000	------------	954,000
------------	423 000	760,000	72,000	1,255,000	362,000	1,617,000
Joaquin River---	(1)159,000	------------	------------	159,000	------------	159,000
Joaquin River---	(1)23,000	(1)39,000	------------	62,000	------------	62,000
------------	------------	(1)20,000	------------	20,000	------------	20,000
------------	------------	(1)27,000	------------	27,000	------------	27,000
mento River---	------------	------------	(2) (4)25,000	25.000	(2)123,000	148,000
Joaquin River---	(1)692,000	(1)56,000	------------	748,000	------------	748,000
------------	874,000	142,000	25,000	1,041,000	123,000	1,164,000
Joaquin River---	(1)68,000	(1)477,000	------------	545,000	------------	545,000
------------	------------	(1)1,764,000	------------	1,764,000	------------	1,764.000
mento River---	------------	------------	(2) (4)87,000	87,000	(2)433,000	520.000
mento River---	------------	------------	(2) (4)74,000	74,000	(2)368,000	442,000
------------	------------	------------	161,000	161,000	801,000	962,000
------------	(1)361,000	(2)100,000	------------	461,000	------------	461,000
mento River---	------------	------------	(2) (4)4,000	4,000	(2)22,000	26,000
------------	361,000	100,000	4,000	465,000	22,000	487,000

the delta.

return flow and surplus waters originating in the lower San Joaquin Valley and intercepted for reuse behind the dams of the San Joaquin River Pumping System. All of the water furnished in this area would be a surface irrigation supply, with none of the supply obtained through utilization of underground storage.

The data presented in Table 138 demonstrate that, under the proposed ultimate State Water Plan in the San Joaquin River Basin, the water requirements of the areas to be served under ultimate development would be adequately met in each hydrographic division, based upon the forty-year period of run-off considered from 1889 to 1929. In addition, the supplies made available for the areas on the east side of the upper San Joaquin Valley south of the San Joaquin River would have resulted in a net accumulation of 6,000,000 acre-feet of water stored in the underground reservoirs at the end of the forty-year period considered. The average seasonal amount of water that would have been required to be imported from the Sacramento River Basin would have been about 2,000,000 acre-feet, exclusive of an average seasonal amount of about 1,000,000 acre-feet of return flow and surplus water from the lower San Joaquin Valley intercepted by the San Joaquin River Pumping System and utilized in the areas served by the San Joaquin River and Mendota-West Side pumping systems, which would be replaced in the delta by Sacramento River water.

Summarizing the accomplishments with respect to water supply and water requirements, the operation of the ultimate State Water Plan would furnish for the San Joaquin River Basin:

1. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of a net area of 1,810,000 acres of irrigable land in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley, after deducting from the full natural run-off of the lower San Joaquin River tributaries, 565,000 acre-feet per season for an adequate and dependable irrigation supply for 205,000 acres of land embracing all of the net irrigable mountain valley and foothill lands situated in the lower San Joaquin Basin at elevations too high to be irrigated by gravity from the major reservoir units.

2. A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of Classes 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley.

3. A supply of 1,570,000 acre-feet per season, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of all of the net irrigable area of 772,000 acres of Classes 1 and 2 lands lying on the western slope of the upper San Joaquin Valley and 13,000 acres of Classes 1 and 2 lands in the Columbia Canal area.

In addition to the water supplies furnished, an average annual electric energy output of 728,500,000 kilowatt hours would be generated at the major reservoirs in the San Joaquin River Basin incidental to their primary operation for irrigation; additional flood protection would be effected on several of the major streams (see Chapter IX); and navigation would be improved on the San Joaquin River above Stockton (see Chapter X).

CHAPTER VIII

INITIAL DEVELOPMENT OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

The initial development of the State Water Plan in the San Joaquin River Basin is proposed as the first progressive step in the consummation of the plan for ultimate development set forth in Chapters VI and VII. It is designed primarily to meet the immediate pressing needs of existing developments. Certain areas in the basin, especially in the upper San Joaquin Valley and in the San Joaquin Delta region, in recent years have been and are now experiencing serious problems of water shortage, the adequate solution of which would require the construction and operation of initial units of the State Water Plan if the productive resources and investment in present developments are to be maintained. The basic objective of the initial development is to furnish additional water to meet the present deficiencies between supply and demand in these developed areas. Added to this is the desirability of providing additional flood protection and improving navigation on the San Joaquin River above Stockton.

As in the plan for ultimate development, the initial development in the San Joaquin River Basin is closely related to and interdependen with that in the Sacramento River Basin because the San Joaqui Valley is dependent upon the Sacramento River Basin for supple mental water supplies required to fully meet the present demands The initial units in the two basins constitute a unified project for th immediate development of the State Water Plan in the entire Grea Central Valley and would be operated coordinately to adequately an completely meet the present needs for the development, regulation distribution and utilization of the water resources.

In evolving a plan for initial development in the San Joaqui River Basin, the following criteria have been adopted:

1. The plan must be so designed as to furnish an adequate su plemental supply to those developed areas with a permanen deficiency, not remediable by the development of their loc water supplies.
2. The physical works of the plan must be so designed as to perm of economical enlargement and extension to a capacity an degree required under the provisions of the plan of ultimat development.

The procedure in the evolution of the plan for initial developme was as follows:

1. The location and extent of the present developed areas of pe manent deficiency of water supply were determined.
2. The amounts of deficiency in the areas of inadequate supp and the amounts of supplemental water required were estimate
3. The economic and logical sources of supplemental supply we determined and the amounts of water obtainable from tho sources estimated.

4. The physical works necessary for furnishing this supplemental supply to the areas of deficiency were determined with careful consideration of the future additional water requirements of the areas.
5. Capital and annual costs of the physical works and revenues anticipated from sale of water and power were estimated.

Immediate Water Problems in San Joaquin River Basin.

A study of present irrigation development in the San Joaquin River Basin reveals that the lower San Joaquin Valley, with the exception of the San Joaquin Delta Region, has an adequate and dependable water supply for present requirements.

In the Sacramento-San Joaquin Delta, the available inflow from the Sacramento and San Joaquin river systems during recent years of generally subnormal run-off has been insufficient during certain months in several years to meet the consumptive demands in the delta and to keep the water fresh as against the invasion of saline water from the bay. Invasion of saline water has rendered the water in the delta channels unfit for irrigation and other uses, not only for the delta lands but also for the adjacent uplands and in the area adjacent to Suisun Bay. The immediate water problems in the delta and adjacent areas and the methods for their solution are presented in detail in other reports.* A few relatively small areas in hydrographic divisions 12 and 13 are in need of some additional water to meet present water requirements, but it appears that the amount of water required can be obtained from local sources through the development of facilities by local interests.

In the upper San Joaquin Valley, a study of existing conditions of irrigation development reveals an area in which many of the local supplies are inadequate to support existing development. On all the streams tributary thereto, there long since has been effected a very high degree of utilization of run-off without surface storage regulation. For many years, therefore, while the irrigated areas devoted to annuals have varied with surface water supplies, the expansion of the irrigated areas devoted to permanent crops has occurred chiefly through the development of ground water supplies. With limited or no surface supplies, the replenishment of ground water storage, commonly resulting from the use of ample surface applications, is lacking in many of these areas. In some localities, expansion of the irrigated areas has continued to such an extent that the net draft on ground water storage exceeds the average seasonal replenishment from whatever local sources are available. The result has been a depletion of ground water storage, which is indicated by a continuously receding water table.

Determination of Developed Areas with Deficient Water Supply and Amounts of Water Shortage.

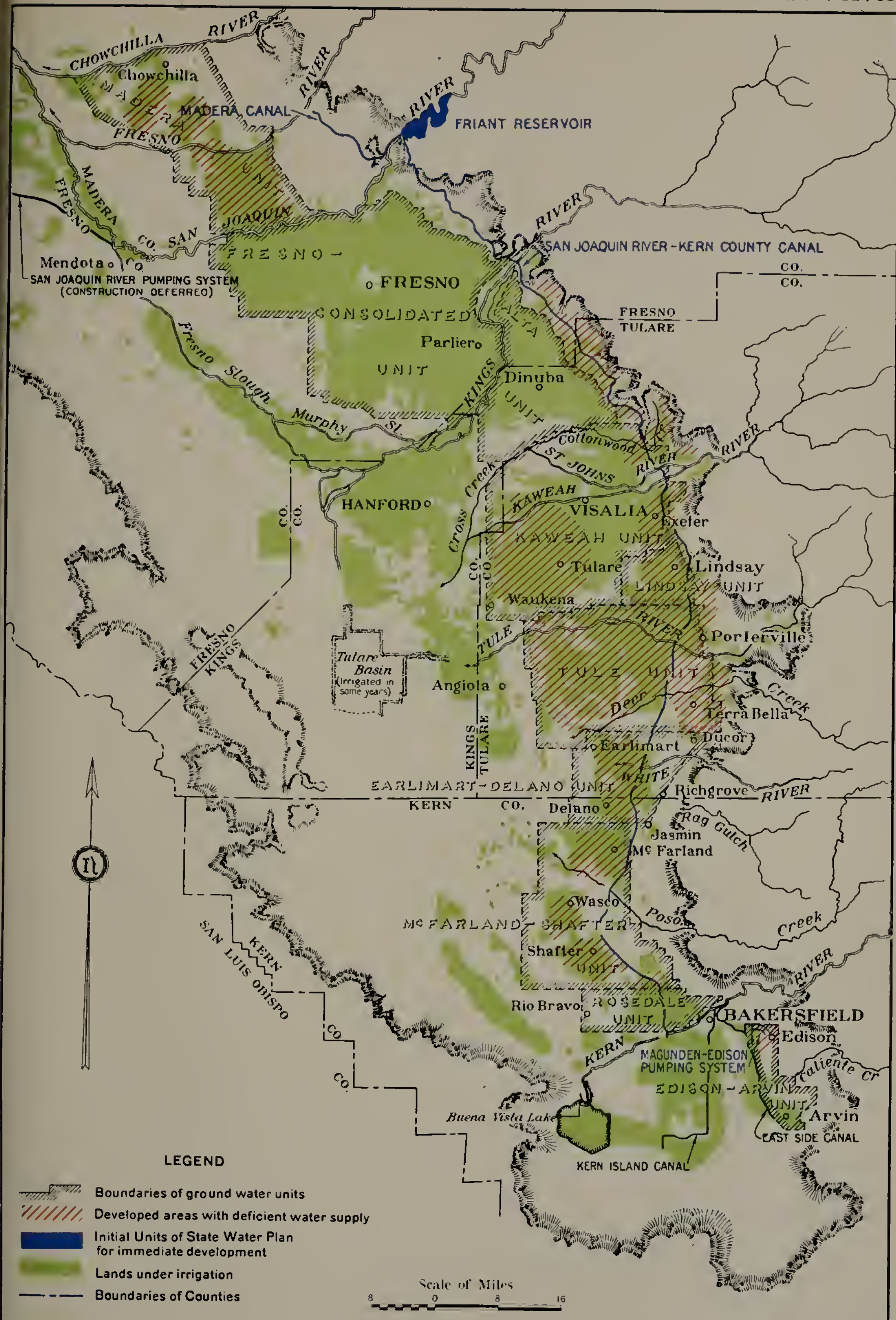
In order that the location and extent of the developed areas of deficient water supply in the upper San Joaquin Valley could be determined, a detailed study of existing development was made involving the elements of the available local water supplies, the irrigated

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.
Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.
Bulletin No. 28, "Economic Aspects of a Salt Water Barrier below Confluence of Sacramento and San Joaquin River," Division of Water Resources, 1931.

areas and the conditions of ground water storage. The results have been presented in Chapter IV. This study covered the area in the five southern counties of the valley, namely, Madera, Fresno, Tulare, Kern and Kings. For convenience of study, areas within the first four counties were divided into ten smaller units, designated as the Madera, Fresno-Consolidated, Alta, Kaweah, Lindsay, Tule-Deer Creek, Earlimart-Delano, McFarland-Shafter, Rosedale and Edison-Arvin ground water units. The term "ground water unit" was applied to these areas as the study dealt primarily with an analysis of the ground water conditions underlying each. The location of these units, described in detail in Chapter IV, is shown on Plate LXVIII, "Ground Water Units and Developed Areas with Deficient Water Supply in Upper San Joaquin Valley." Lands under irrigation, developed areas with deficient water supply and initial units of the State Water Plan for immediate initial development in upper San Joaquin Valley also are shown on this plate. Kings County and other areas not included in the above named ground water units also were studied but on a different basis.

An analysis was made for each ground water unit to determine as closely as possible the deficiency of supply, if any, that has been experienced for the lands already under irrigation. This analysis covered the eight year period 1921–1929 for which the complementary data were available on surface water supply to the unit, irrigated areas and ground water levels. The length of the period was fixed by the length of continuous records of ground water conditions. In the Kern County units, the records covered the 9–year period 1920–1929 but, in order to make the studies in all units comparable, the 8-year period was used throughout. Data on some 4000 wells, distributed over the entire area, were available for the study.

The boundaries of ground water units were selected in each case to include irrigated lands with a common source of water supply, whether from surface or underground development. Based upon a year by year study for the period 1921–1929 of the collected data on surface inflow, irrigated area and change in ground water level for each ground water unit, it has been possible to estimate the average seasonal inflow required to support the existing irrigation development and prevent a continuous recession of the ground water. The seasonal inflow into any particular area is defined as that part of the tributary run-off actually entering the area, less known exportations and surface outflow from the area. Since ground water is a form of cyclic storage, fluctuations in level are permissible from year to year so long as the minimum levels do not increase pumping lifts beyond the economic limit. The fact that, during a period of subnormal inflow, a lowering in the ground water has occurred in an area of pumping development does not necessarily mean that it is an area with a supply inadequate to meet existing irrigation demands. If, however, the long-time available mean seasonal inflow to the ground water unit is less than the estimated mean seasonal water requirements, it is concluded the area is one of deficient local supply as now utilized. On this basis, the conditions in each ground water unit have been studied and the period of depletion and the total and mean seasonal amounts of depletion of ground water storage estimated. Estimates of depletion in each unit are for the entire area of the unit, regardless of the percentage actually



GROUND WATER UNITS

AND

DEVELOPED AREAS WITH DEFICIENT WATER SUPPLY

IN

UPPER SAN JOAQUIN VALLEY

irrigated. In some units, portions of the area, due to their favorable position on the schedule of utilization of local surface supplies, are without deficiency, even in periods of subnormal run-off. In such units, the ground water contour maps for each year of record show clearly, by cones of depression in the water table, where the overdraft upon the ground water is greatest. It is not feasible, however, to define exactly the boundary of the area of deficiency or to say what part of the overdraft is due to pumping in adjacent areas. For these reasons no attempt has been made to lay down the exact boundaries of the areas of deficiency within each ground water unit, but only to indicate their general location and to estimate the amount of deficiency between supply and present draft.

Utilizing all the available data, there has been presented in Chapter IV a year by year analysis of ground water conditions in each unit for the period 1921–1929. The results of this analysis are summarized in Table 139. In this table are set forth for each unit its total area, the average area irrigated for the period studied, and the total and average seasonal depletion of ground water.

TABLE 139

CHANGE IN VOLUME OF GROUND WATER IN UPPER SAN JOAQUIN VALLEY. SUMMARY BY GROUND WATER UNITS, 1921-1929

Unit	Area of unit, in square miles	Average area irrigated, in acres	Depletion of ground water, in acre-feet	
			Total	Average per season
Madera	343	69,000	487,000	61,000
Fresno-Consolidated	700	319,900	566,000	71,000
Alta	191	79,000	161,000	20,000
Kaweah	468	133,700	732,000	92,000
Lindsay	64	22,000	148,000	19,000
Tule-Deer Creek	373	67,400	447,000	56,000
Earlimart-Delano	150	21,200	400,000	50,000
McFarland-Shafter	310	50,100	491,000	61,000
Rosedale	79	12,000	69,000	9,000
Edison-Arvin	51	18,600	103,000	13,000

The depletion of ground water for the period 1921–1929 in the several ground water units, as set forth in Table 139, reflects the relation between the inflow and the net draft during the period of ground water record. It so happens that the entire range of continuous observations of ground water conditions falls within a period of subnormal run-off. The occurrence of a season of normal run-off during this dry period is sharply reflected in the ground water conditions in some of the units.

It is not sufficient to use the data of a series of dry years, alone, in determining which of the ground water units have inadequate local supplies. Examination also must be made of the relation between average seasonal inflow during the recent period of depletion and the seasonal inflow for various other periods. In this investigation, the seasonal inflow for each ground water unit was taken as that part of the estimated tributary run-off practicable of utilization through the full use of existing physical works and underground storage, less exportation and surface outflow from the area, as under present conditions of development. The records of exportation and surface outflow considered were obtained from outflow data for seasons of corresponding run-off during the period of measurement. Estimates of inflow were made for the 40-year period 1889–1929, the 20-year period 1909–1929, the 8-year period 1921–1929 for which ground water depletion was determined and the 5-year period 1924–1929.

A comparison of the seasonal inflow for the period of depletion and other periods, with the average seasonal depletion in ground water for each unit is set forth in Table 140. The average seasonal inflows shown in the table for the Tule-Deer Creek unit for the various periods include a supply for about 5000 acres of developed lands lying east of the unit and for which no records of ground water or diversion are available. Similarly for the Kaweah unit, the figures of average seasonal inflow include a supply for 3600 acres lying east of the unit. It was impracticable to segregate the use on these two particular areas from the total inflow which should be done to obtain exact figures for the inflow into these respective units. However, this approximation does not affect the conclusions as to the deficiencies in supply in these units.

TABLE 140

COMPARISON OF DEPLETION OF GROUND WATER STORAGE WITH AVAILABLE LOCAL SUPPLIES IN UPPER SAN JOAQUIN VALLEY. SUMMARY BY GROUND WATER UNITS

Ground water unit	Average seasonal depletion in ground water during period 1921-1929, in acre-feet	Average seasonal inflow to ground water unit, in acre-feet				Required average seasonal inflow to prevent depletion, in acre-feet[1]
		40-year period, 1889-1929	20-year period, 1909-1929	8-year period, 1921-1929	5-year period, 1924-1929	
Madera	61,000	144,200	121,000	111,400	101,400	172,400
Fresno-Consolidated	71,000	770,000	680,000	537,000	568,200	608,000
Alta	20,000	225,000	182,000	133,900	145,300	153,900
Kaweah	92,000	370,000	297,000	250,800	248,200	342,800
Lindsay	19,000	(2)	(2)	13,900	14,000	[1]44,000
Tule-Deer Creek	56,000	155,000	130,000	92,300	87,100	148,300
Earlimart-Delano	50,000	4,000	3,500	2,800	2,800	52,800
McFarland-Shafter	61,000	86,000	79,000	38,900	27,100	99,900
Rosedale	9,000	87,000	81,000	46,700	41,200	55,700
Edison-Arvin	13,000	37,000	29,000	23,600	22,100	36,600

[1] Sum of average seasonal depletion and average seasonal inflow for eight-year period, 1921-1929, excepting Lindsay unit. In this unit the sum of these items does not represent an adequate supply and therefore a net use of two acre-feet per acre is assumed.
[2] Inflow to Lindsay unit is an importation from the Kaweah River of about 14,000 acre-feet annually, beginning in 1918. This was taken into consideration in estimating the net inflow to the Kaweah unit.

It is obvious that the depletion of the underground storage repre sents an overdraft upon the available supply and, therefore, the sum o the average seasonal depletion and the average seasonal inflow durin the period of depletion should represent the amount of average seasona inflow which would have been adequate to maintain stable ground wate conditions during that period. The summations of average seasona inflow and depletion for the 8-year period of record are shown in th last column of Table 140 for the purpose of determining whether eac unit is one of permanent deficiency in local supply as related to th available inflow for periods other than the period of depletion. B comparing the quantities in the last column with the average seasona inflow for each of the five, eight, twenty and forty-year periods endin in 1929, the condition as to permanent deficiency is indicated.

The results of the detailed studies as to deficiency or adequacy of water supply for the present irrigation development in each ground water unit and other areas in the upper San Joaquin Valley are presented in the following paragraphs:

The Madera Unit—The Madera unit is one in which the present average draft upon the ground water evidently exceeds the replenishment that would be effected even with the average utilizable water supply over a 40-year period including both wet and dry periods. During the 8-year period, the irrigated area in this unit increased from 60,000 acres in 1921 to 81,000 acres in 1929, segregated as follows: Deciduous fruits 8200 acres, vines 25,300 acres, alfalfa 16,200 acres, field crops 2000 acres, cotton 27,400 acres, pasture 1300 acres and truck 600 acres. The sources of water supply now utilized in this area are the Chowchilla and Fresno rivers, augmented by an importation of about 10,000 acre-feet each year from the Merced and San Joaquin River drainage areas. The average seasonal inflow available during this period was 111,400 acre-feet. With this inflow, the average seasonal depletion of ground water was 61,000 acre-feet and that during the season 1928–1929 was 146,000 acre-feet. The 40-year average seasonal inflow available is estimated as 144,200 acre-feet, or 32,800 acre-feet in excess of that during the period of ground water record. Comparing this excess with the 61,000 acre-feet of average seasonal depletion, it is obvious present development could not have been supported without an overdraft on the ground water storage.

The Fresno-Consolidated Unit—The data on the Fresno-Consolidated unit indicate no permanent depletion of its ground water storage. The Fresno and Consolidated irrigation districts, which are included within this unit, have been under practically full irrigation development for many years. The area irrigated in 1929 consisted of 1100 acres of citrus and 40,700 acres of deciduous fruits, 168,700 acres of vines, 35,300 acres of alfalfa, 31,700 acres of field crops, 9600 acres of cotton, 34,500 acres of pasture and 200 acres of truck, totalling 321,800 acres. The Fresno District has extensive diversion rights of relatively early priority on Kings River and receives a more dependable water supply, both in amount and in distribution through the season, than other large areas served from Kings River. From the inception of irrigation in this area to the beginning of the period of this study, the ground water had risen from 30 to 60 feet above its position prior to irrigation. This resulted in the water-logging of a considerable portion of the area now in the district and it is only with the development of pumping and the recent series of dry years that conditions favorable to the proper production of crops in the portions of the district formerly water-logged have been reached. The depth to ground water over the greater part of the Fresno District varies from 10 to 25 feet. At the extreme northern edge of the district the depth to ground water ranges from 50 to 70 feet. The average total lowering in different parts of the district for the 8-year period of record was 6.5 feet. The water rights of the Consolidated District furnish only a limited supply at medium to low stages of Kings River, but yield a large flow during the short period of high water. This condition results in an unfavorable distribution of the season's total supply and for this reason practically all canal-irrigated lands are equipped for supplemental pumping. The average depth to ground water varies from 10 to 25 feet, and is about 50 feet in an area of two or three square miles along the bank of Kings River, just east of Parlier. The average total lowering during the 8-year period varied from 5 to 10 feet, with a small area near Kings River having a lowering of 15 feet.

The quantities in Table 140 show that, while the seasonal inflow has been somewhat inadequate during the recent years of subnormal run-off, the average seasonal inflow of utilizable water supply for either the 20 or 40-year periods preceding 1929 would have supported the present development of the unit. For the 5 and 8-year periods, the average deficiency in seasonal inflow into this unit was about one-tenth of the full requirement.

Lying northeast of and irregularly situated within a strip of territory from one to two miles in width and 20 miles in length adjacent to and paralleling the Enterprise Canal of the Fresno Irrigation District, are small pump-irrigated areas totaling 3300 acres and having no water rights in said canal. The irrigated areas contain 180 acres of citrus and 80 acres of assorted deciduous fruits, 1750 acres of figs, 40 acres of alfalfa and 1250 acres of vines. The source of supply for ground water replenishment in these areas consists of drainage from the lower foothills of the Sierra between the Kings and San Joaquin rivers through Dry, Dog and Fancher creeks and Sales Creek, a tributary of Dog Creek. The average seasonal run-off of these streams for the 8-year period, 1921–1929, is estimated at 7900 acre-feet, which amount is sufficient to support existing development without permanent overdraft on ground water.

The Alta Unit—The Alta unit, which consists principally of the Alta Irrigation District, is similar to the Fresno-Consolidated as to the sufficiency of its water supply, in that, for the long-time average, the inflow of utilizable water supply is adequate to support the present irrigation development, with the possible exception of an area of 5000 acres along its eastern rim in which a total lowering of ground water of from 25 to 35 feet occurred during the period of observation. The total area irrigated in 1929 was 68,450 acres, consisting of 800 acres of citrus and 8800 acres of deciduous fruits, 47,300 acres of vines, 1900 acres of grain, 6000 acres of alfalfa, 450 acres of field crops, 1800 acres of cotton, 1100 acres of pasture and 300 acres of truck. In the central portion of the district, the total lowering has been from 5 to 15 feet and 25 feet in a very limited area. The present depth to ground water varies from 15 to 35 feet. The data for this unit show that, with proper distribution of local supplies, the average seasonal inflow for either the 20- or 40-year periods would have been adequate to meet the present needs of the unit.

Lying east of and immediately adjacent to the Alta district is the Foothill Irrigation District, some 50,000 acres in extent and with a present developed area of 11,000 acres which in 1929 consisted of 3600 acres of citrus and 3000 acres of deciduous fruits and 4400 acres of vines. This district was organized under a plan calling for the exchange of a supply pumped from ground water along Murphy Slough for a gravity diversion right on Kings River. The plan has never been consummated and, with practically no run-off tributary to the area, the district is entirely without a water supply. No continuous record of ground water observations has been maintained in the Foothill District, but a few recent observations indicate that such ground water supply as originally underlay the area is practically exhausted. The present developed area of 11,000 acres, combined with the 5000 acres of the higher rim lands of the Alta unit, is considered to be one of practically zero water supply and has been so treated in estimating the requirements for importation of supplemental water supplies under initial development.

The Kaweah Unit—The Kaweah unit, including all of the area naturally dependent upon the Kaweah River for its water supply, is apparently one in which, over the 40-year period, the local sources of supply are adequate. However, the higher eastern portion of the unit around Exeter is so situated that it receives no portion of the available surface flow so that its principal source of ground water replenishment must be from the west through relatively impervious materials. A deep trough of depression in the ground water is revealed by a study of ground water levels in this area near Exeter. The total lowering during the period of record has been from 20 to 50 feet. The present depth to ground water is from 50 to 110 feet. This portion of the unit has relatively nonabsorptive soils and it is concluded additional water must be provided, chiefly in the form of a surface irrigation supply. At the extreme north edge of the unit, but slight lowering of the water table has occurred during the period of record. In the areas served by canals the lowering has been from 5 to 15 feet. Farther from canal service and near the town of Tulare, extensive pumping development has resulted in a lowering of from 25 to 35 feet. While the tabular quantities show that the 40-year average seasonal inflow is adequate to support existing development, it is judged that its unequal distribution throughout the area in accordance with existing diversion rights probably would result in some permanent depletion.

The irrigated area, which in 1929 totaled 128,500 acres, consisted of 12,000 acres of citrus and 23,500 acres of deciduous fruits, 22,000 acres of vines, 2000 acres of grain, 38,000 acres of alfalfa, 6000 acres of field crops, 14,500 acres of cotton, 9500 acres of pasture and 1000 acres of truck.

The Lindsay Unit—The Lindsay unit lies between the deltas of the Kaweah and Tule rivers in a locality of small tributary inflow. It is devoted largely to citrus culture and is one of the oldest pumping areas in the San Joaquin Valley. The irrigated area in 1929 consisted of 13,000 acres of citrus and 4000 acres of deciduous fruits, 2800 acres of vines, 500 acres of alfalfa, 400 acres of field crops, 1200 acres of cotton and 100 acres of truck, totaling 22,000 acres. This unit is relatively distant from the Tule and Kaweah rivers and out of the line of ground water movement from the deltas of these streams. The lack of any active source of ground water replenishment is shown by the rapid rate of lowering which has occurred. Practically the only source of inflow to this area during the period of record has been the seasonal importation of about 14,000 acre-feet pumped from a well field at the head of the Kaweah Delta by the Lindsay-Strathmore Irrigation District. The total ground water lowering during the period 1921–1929 averaged 55 feet, with a range of 25 to 75 feet. The present depth to ground water varies from 25 to 175 feet. The data show that an imported supplemental water supply is required to meet the present needs of this area.

The Tule-Deer Creek Unit—The Tule-Deer Creek unit includes lands dependent upon the Tule River and Deer Creek for their ground water replenishment. The irrigated area in 1929 consisted of 3700 acres of citrus and 5800 acres of deciduous fruits, 8000 acres of vines, 1100 acres of grain, 9500 acres of alfalfa, 2400 acres of field crops, 34,000 acres of cotton, 5200 acres of pasture and 500 acres of truck, totaling 70,200 acres. The total average lowering of ground water during the 8-year period of record has been 23 feet. Along the main line of the Southern Pacific Railroad the depth to ground water varies from 50 to 70 feet. At the westerly edge of the unit the depth is about 30 feet and at the eastern rim of the unit southeast of Terra Bella the depth to ground water is 200 feet. Although the forty-year average seasonal inflow shows a slight excess above the average requirement for this area, the average seasonal inflows for the 20, 8 and 5-year periods show marked deficiencies. It is concluded that this area is one requiring an imported supplemental water supply. Over the southeastern portion of this unit the soil types are considered nonabsorptive and an imported water supply, delivered chiefly in accordance with a surface irrigation demand, will be required.

Area East of Tule-Deer Creek Ground Water Unit—East of and adjacent to the Tule-Deer Creek Unit are small nonabsorptive irrigated areas totaling 6000 acres, about 1000 acres of which have an adequate surface supply. The irrigated areas in 1929 consisted of 5000 acres of citrus and 600 acres of deciduous fruits and 400 acres of vines.

The Earlimart-Delano Unit—The Earlimart-Delano unit includes the east side valley lands from Earlimart and Ducor on the north to the southern limit of the Delano development in northern Kern County. This is an area of extremely limited tributary run-off. White River is the only stream draining higher foothill areas. Rag Gulch drains additional low foothill areas. All irrigation development is by pumping. The irrigated area increased from 11,600 acres in 1921 to 30,500 acres in 1929, segregated as follows: Citrus fruits, 500 acres; deciduous fruits, 1000 acres; vines, 13,000 acres; alfalfa, 1000 acres; field crops, 1000 acres and cotton, 14,000 acres. The figures in Table 140 show the great contrast between available inflow and the overdraft to date. East of Delano a maximum lowering of the water table of 70 feet has occurred in the 8-year period, with a lowering of 50 feet shown for a large area. At the north end of the unit, depths to ground water range from 50 feet at Earlimart to 200 feet just east of Ducor, with a midway depth of 100 feet. At the south limit of the unit, the range is from 25 feet at the west to 200 feet near Jasmin on the east, with a midway depth of 125 feet just east of Delano. An examination of the seasonal inflows and the depletion of ground water in this unit shows that it requires an additional supply almost equal to its total irrigation needs for present development.

The McFarland-Shafter Unit—The McFarland-Shafter unit, bordering the Earlimart-Delano unit on the south, extends southward 21 miles and includes within its boundaries the highly developed areas around the towns of McFarland, Wasco and Shafter. The areas irrigated in the vicinity of these towns totaled 49,800 acres in 1929 and consisted of 8400 acres of deciduous fruit, 11,700 acres of vines, 10,000 acres of alfalfa, 7500 acres of field crops and 12,200 acres of cotton. These irrigated areas are dependent entirely upon a supply pumped from the underlying ground water. Included within this unit also are some 60,000 acres of Class 1 land lying for the most part above the pumping developments, which are properly located to receive surface irrigation from existing canals of large capacity but with diversion rights of late priority on the Kern River. The irrigated area devoted chiefly to annuals varies from year to year with the water supply. With the exception of Poso Creek, which is estimated to contribute a long-time mean seasonal replenishment of 17,000 acre-feet to the ground water of this unit, the only source of replenishment for the ground waters underlying the pump-developed areas are the losses of conveyance and distribution from the supplies delivered through canals to the large area dependent upon surface irrigation. These canal-irrigated lands are largely in one ownership and, in past periods of high run-off, have been liberally supplied with water, the effect of which during the period from 1880 to 1920 was to raise the natural water table from 50 to 60 feet. Pumping development began about 1910 and has continued steadily ever since. At approximately the same time the pumping draft reached an amount about equal to the average seasonal replenishment, a period of subnormal run-off began. The effect of these two conditions of steadily increasing draft and diminishing inflow is sharply reflected in the data for this unit. The maximum total lowering of the water table during the period of ground water record has been 40 feet at McFarland, about the same near Wasco, and about 30 feet at Shafter. The depths to ground water at these points as of October 1929, were from 50 to 100 feet at McFarland and from 50 to 75 feet in the vicinity of Wasco and Shafter. If auxiliary pumping were practiced in the adjoining canal-served area, from which replenishment is now largely received, these declines in water level would be further increased.

The data for this unit indicate that even the 40-year average seasonal inflow under present conditions of water supply development and utilization would have been entirely inadequate to meet the water requirements of this area. The propriety of including these pumping areas in an immediate initial project for importing supplemental water supplies to this unit may be questioned inasmuch as earlier studies of the Kern River area for a local project indicate that, if properly utilized through the combined medium of surface and ground water storage, the run-off of Kern River is adequate to serve all the area lying within the outlines of existing canal systems and dependent more or less directly thereon for a water supply. However, the existing status of the recognized diversion rights on this stream is such that, without construction of a complete system of regulatory works and some adjustment of present rights, no additional water could be furnished to remedy the conditions of receding ground water underlying the pumping areas of McFarland, Wasco and Shafter, which lie outside the Kern River alluvial fan and within that of Poso Creek.

Moreover, as will be shown subsequently, no additional utilizable water supply could have been obtained by the additional provision of storage regulation on Kern River during the period 1917–1929; and the cost of water imported from the San Joaquin River would be less than the cost of new water which would be developed on Kern River from the run-off that would have been available during the 40-year period 1889–1929 by combining the fullest practicable amount of surface storage regulation with underground storage and pumping. It is concluded, therefore, that this area is one requiring an imported supplemental water supply.

The Rosedale Unit—The Rosedale unit, lying between the McFarland-Shafter unit and Kern River, is one served by supplemental gravity and pumped supplies. Being adjacent to Kern River and traversed by an extensive canal system, it is subject to heavy recharge and large outflow to the west. While some lowering of the water table has occurred during the recent dry years, the long-time average available inflow is far in excess of that required to support existing development. In earlier years of plentiful water supply, a considerable portion of this unit was subject to water-logging. After a lowering of about 10 feet during the 8-year period of record, the depth to ground water in the main portion of the area is about 20 feet. The data show that there is no permanent shortage of supply in this unit.

Canal-Irrigated Area South of Kern River—South of the Kern River lies an agricultural area of some 100,000 acres which for forty years has been in the same general state of irrigation development. This area is served from Kern River under diversion rights of varying priorities with a water supply which, if uniformly distributed and intensively utilized, would be adequate to support existing development. The ground water problem in this area is one of drainage. With the recent series of dry years the ground water is at a depth 10 feet from the ground surface.

At the eastern edge of the foregoing canal-irrigated area, but separated from the main body of that area by the alkali-impregnated topographic trough of the old South Fork channel, lies the East Side Canal area of 16,000 acres. Of this area, some 6200 acres of service right lands in the past 30 years have received by diversion from Kern River an average gross water supply of four acre-feet per acre. A similar area is served solely from ground water sources and supplemental pumping is practiced on much of the service right area. While lowering of from 5 to 10 feet in the water table has occurred during the period of record, due to subnormal inflow, the average supply is considered adequate to maintain existing irrigation development under both canal and pumping service. Therefore, it is not considered a an area requiring a supplemental supply.

The Edison-Arvin Unit—Contiguous on the east to the area served by the East Side Canal lies the Edison-Arvin unit. This unit include in its southern portion the entire area developed under pump irrigation on the cone of Caliente Creek and around the town of Arvin. In its northern portion it includes the citrus development around Edison and the area devoted to both citrus and deciduous fruits extending o both sides of the Southern Pacific Railroad from Edison westward past Magunden toward Bakersfield. The area irrigated in 1929 totaled 20,000 acres, consisting of 1000 acres of citrus and 4000 acres of deciduous fruits, 7500 acres of vines, 4000 acres of alfalfa, 3000 acres of cotton and 500 acres of truck. The principal source of replenishment for the ground water of this unit is the run-off of Caliente Creek. The existence of a cone of depression under this area, caused by heavy pumping draft during the past 5 years, has lowered the water table to an elevation below that under the East Side Canal 3 miles away. This condition can not long continue without appreciable movement of ground water probably occurring from the canal area to the Arvin area. The total irrigation development under pumping on the Caliente Creek fan is 17,400 acres and the long-time mean yield of the tributary drainage area is 37,000 acre-feet. During the period of ground water record, 1920–1929, the average seasonal inflow from Caliente Creek is estimated as 22,900 acre-feet and under these conditions there has occurred a lowering of from 10 feet to 30 feet with resulting depths, as of October 1929, varying from 70 feet near the East Side Canal to 200 feet at the eastern limit of the development. The data indicate that, while the 40-year average inflow shows a slight excess over the mean requirement, the 20-year average inflow is inadequate for a full supply. The northern portion of this unit, the area of permanent deficiency, can not avail itself of any of the local supply from Caliente Creek because of its relative elevation and impervious subsoil. The lack of ground water movement from the developed area around Arvin to that around Magunden and Edison is indicated on Plate VIII, which shows a slight raise in the water table underlying the unirrigated area which separates the cones of depression underlying each of the developed areas.

A study of the geologic, run-off and ground water conditions of the Magunden-Edison area indicate that the principal source of replenishment is from the apex of the delta cone of the Kern River as that stream passes beyond the impervious toe of Kern Bluffs at Bakersfield, and from the East Side Canal. From Bakersfield to the bottom of the ground water depression underlying this development, the water table descends 50 feet in 7 miles. From the East Side Canal the fall is about 6 feet in 2 miles. These slopes indicate some movement of ground water, but they have been created by a total lowering of 20 feet for the period of record, 1920–1929. This movement, however, is inadequate to support the existing development. It is estimated that a net area, consisting of 1000 acres of citrus fruits and 1600 acres of olives and deciduous fruits in the Magunden-Edison area, is in need of a supplemental supply of 2 acre-feet per acre, or a seasonal total of 5200 acre-feet.

Other Areas Studied—In selecting areas in need of immediate relief, those used for annual crops under canal irrigation varying in adequacy from year to year and those of high ground water, where good opportunities are afforded for pumping development, have not been included. Within these excluded classes fall Kern County areas in the Buena Vista Water Storage District, Pioneer Canal area, Buttonwillow and Semitropic ridges and the canal-irrigated areas above discussed in the McFarland-Shafter unit.

The Kings County Canal area also falls in these classes. It lies immediately south of the Kings River channel and contiguous to the Kaweah unit on the west. The gross area is 159,000 acres served by gravity waters from the Kings River under the diversion rights of the Peoples, Last Chance and Lemoore canals. The water supply has been sufficient to cause high ground water under much of the area. Some supplemental pumping of ground water supplies has been practiced in recent years, but has not attained proportions comparable with the upper Kings River areas. During the recent years of subnormal run-off the water table has receded somewhat. In the fall of 1929, depths to ground water varied from 10 to 15 feet. In normal years drainage would be beneficial to this area.

The Tulare Lake area, which is here used to include the total area of the Corcoran and Lakelands irrigation districts and Tulare Lake Water Storage District, for the most part also falls in these classes. It is served by water diverted from the Kings and Kaweah rivers mainly at high stages. Due to the deficiency of water supply during the recent series of years of subnormal run-off and the menace of floods in years of large run-off, the bed of Tulare Lake, which has for the most part been reclaimed by levees, is devoted chiefly to grain farming. On the higher lands lying principally in the Corcoran District, cotton is the predominating crop with smaller areas of alfalfa and grain. The cropped areas vary considerably from year to year. The area irrigated in 1929 totaled 71,300 acres, consisting of 12,650 acres of grain, 2960 acres of alfalfa, 360 acres of field crops and 15,850 acres of cotton in the Corcoran District; 4320 acres of grain and 160 acres of alfalfa in the Lakelands District; and 34,100 acres of grain, 200 acres of alfalfa and 700 acres of cotton in areas outside of these districts. Ground water supplies in the Tulare Lake area are obtained mainly from the deeper strata. In this area artesian wells formerly were obtainable. The formation is considered relatively nonabsorptive and a definite natural barrier along the eastern rim seems to resist ground water movement into the area from the east. The depth to ground water in wells in June of 1929 was about 100 feet, as compared with that of 30 feet in the area just east of Corcoran on the outer Tule Delta. This area could be adequately served either from the Kings River, if regulated, by means of pumping and surface supplies or from the excess ground water supplies which could be made available on the lower edge of the Kaweah and Tule deltas under the plan of immediate initial development.

There is a large irrigated area lying north of the lower Kings River and southwesterly of the Fresno and Consolidated irrigation districts which also comes within the classes noted. It is supplied by gravity diversion chiefly from Kings River and by pumping from wells and natural drains. This area is divided into organized districts and groups namely, Laguna Irrigation District, Riverdale Irrigation District, Crescent Irrigation District, Cuthbert-Burrel lands, Stinson Irrigation District, Residual Murphy Slough group, James Irrigation District and Tranquillity Irrigation District. The total gross area included within these districts and groups is about 135,000 acres. The area irrigated in 1929 was 69,000 acres.

The Laguna and Riverdale irrigation districts include the lands between the north bank of Kings River and Murphy Slough. Pumping was begun in this area in recent years and the former high water table appears to be under control. The average depth to ground water in the fall of 1929 was from 10 to 15 feet. The Crescent Irrigation District is situated west of the Riverdale area. Cuthbert-Burrel lands, Stinson Irrigation District and Residual Murphy Slough group are to the north of these areas. Farther north, and adjacent to Fresno Slough, are the James and Tranquillity irrigation districts. All of these areas divert water from Kings River at the higher stages of flow. Supplemental pumping from ground water is practiced when river water is not available. The James and Tranquillity irrigation districts also exercise diversion rights on the San Joaquin River by pumping water backed up Fresno Slough by the Mendota Weir. The James Irrigation District operates both deep wells within the district and shallow wells in the general area of undeveloped land between Fresno Slough and the Fresno Irrigation District. With an estimated mean seasonal pumping draft of 17,000 acre-feet from a battery of shallow wells during the period 1921–1929, a maximum lowering of ground water of 10 feet and an average depth to water table of 20 feet has resulted. The draft of 1929 has been estimated at 24,000 acre-feet. The obvious source of replenishment of these underground supplies is the ground water outflow from the Fresno Irrigation District.

Within the foregoing areas lying north of the lower Kings River, notably under some canals of late priority of diversion right on Kings River serving lands adjacent to the valley trough, are developed lands dependent in part upon ground waters of considerable mineral content. During recent years of deficient canal supply (normally depended on to counteract the toxic effect of the use of mineralized ground waters) some portions of these areas have been insufficiently supplied with fresh water. It is considered possible that portions of these areas may require relief, both for the restoration of soil conditions and relief of ground water draft. This could be afforded through additions of fresh water to their present available surface supplies to overcome the harmful effects of recent increases in the use of ground water.

Estimation of Relative Deficiencies in Water Supply—The depletion of ground water storage during a certain period of years, the amount of which can be ascertained, for an area under irrigation development is not an absolute measure of the degree of water supply shortage, nor is it proof that the area is one of deficient water supply. Several other factors influence the determination of the adequacy of the available supply. A comparison must be made of all elements of supply and demand for the period during which the estimated depletion took place, with similar elements for other periods of record. Continuous records during the 8-year period 1921–1929 of ground water elevations, irrigated areas and water inflow, for the various units of the upper San Joaquin Valley, have made it possible to estimate the depletion of ground water storage for each, and the average seasonal inflow required to maintain the balance between supply and draft.

This period is established by records as one of subnormal run-off in all local streams. As the estimated ground water depletion occurred under conditions of subnormal supply, it is necessary also to determine how much depletion, if any, would have occurred during periods of more plentiful supply, and what the average conditions of supply and draft would have been during longer periods of stream flow record.

In Table 140 there have been set forth for each ground water unit, the average seasonal depletion of ground water which occurred during the 8-year period 1921–1929, the estimated average seasonal inflow which would be required to prevent continuous depletion or in other words the total seasonal water requirements under present conditions, and, for comparison with that requirement, the estimated average utilizable seasonal inflow to each ground water unit for each of the 40, 20, 8 and 5-year periods. The factors used in estimating the relative deficiencies in water supply of the various ground water units are shown in Table 141. For each unit there are set forth for the period 1921–1929 the average irrigated area, the average seasonal lowering of ground water, the required average seasonal inflow to prevent depletion and the average seasonal ground water depletion, expressed in total acre-feet, acre-feet per acre of irrigated area and in per cent of required average seasonal inflow to prevent depletion.

Units now under development having comparatively small lowering of their ground water levels and an average seasonal inflow for the 20-year period 1909–1929 adequate for complete replenishment thereof, are considered to have no permanent deficiencies of water supply even

TABLE 141

FACTORS USED IN ESTIMATING RELATIVE DEFICIENCIES IN WATER SUPPLY OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY, 1921-1929

Unit	Average area irrigated, in acres	Average seasonal lowering of ground water, in feet	Required average seasonal inflow to prevent depletion, in acre-feet[1]	Average seasonal ground water depletion		
				Total acre-feet	Acre-feet per acre of irrigated area	Per cent of required average seasonal inflow to prevent depletion
Madera	69,000	1.4	172,400	61,000	0.88	3
Alta-Foothill[3]	16,000	------------	32,000	32,000	2.00	10
Kaweah	133,700	2.3	342,800	92,000	0.69	2
Lindsay	22,000	6.9	44,000	19,000	0.86	4
Tule-Deer Creek	67,400	2.8	148,300	56,000	0.83	3
Earlimart-Delano	21,200	4.2	52,800	50,000	2.36	9
McFarland-Shafter	50,100	3.1	99,900	61,000	1.22	6
Magunden-Edison	2,600	------------	5,200	5,000	2.00	10
Fresno-Consolidated	319,900	0.8	608,000	[2]71,000	0.22	1
Alta—						
Including 5,000 acres of rim land	79,000	1.4	153,900	20,000	0.25	1
Excluding 5,000 acres of rim land	74,000	------------	143,900	10,000	0.14	
Rosedale	12,000	1.3	55,700	9,000	0.75	1
Edison-Arvin—						
Including 2,600 acres in Magunden-Edison	18,600	2.9	36,600	13,000	0.70	3
Excluding 2,600 acres in Magunden-Edison	16,000	------------	31,400	8,000	0.50	[illegible]

[1] Sum of average seasonal depletion and average seasonal inflow.

[2] Includes present known outflow of about 17,000 acre-feet supplying lands in James Irrigation District, for whic[h] a supplementary supply is provided in plan of proposed immediate initital development.

[3] Comprises area of 11,000 acres in Foothill Irrigation District and 5,000 acres of rim lands in Alta Unit.

though the records of the 1921–1929 period indicate ground water depletion. A study of the data in Tables 140 and 141 shows that the Fresno-Consolidated Unit, Alta Unit (excluding 5000 acres of rim land) and Rosedale Unit fall under this criterion. The Edison-Arvin Unit, excluding 2600 acres in the Magunden-Edison area, also is placed in this classification although the estimated average inflow into the unit for the 20-year period is slightly less than the estimated required average inflow to prevent depletion under present requirements. However, the average inflow, as estimated for a 25-year period, 1904–1929, appears adequate to support existing development.

Units underlain with impervious material and having practically no means of replenishment of ground waters are considered as having a deficiency of a total net use of two acre-feet per acre of irrigated land. An area of 11,000 acres in the Foothill Irrigation District, 5000 acres on the eastern rim of the Alta Irrigation District and 2600 acres in the Edison-Arvin ground water unit, designated as the Magunden-Edison unit, are considered in this class. These areas have no local inflow. The Lindsay Unit of 22,000 acres also falls in this classification, but its requirement is partially met by the annual importation of about 14,000 acre-feet of water pumped from the Kaweah Delta.

Units for which the records show a lowering of ground water levels and a net use or a required average seasonal inflow to prevent depletion exceeding the 20-year average seasonal inflow are considered as areas of permanent deficiency in local supply. The units in this classification are Madera, Kaweah, Tule-Deer Creek, Earlimart-Delano and McFarland-Shafter.

Areas and Amounts of Deficient Water Supply and Required Importations of Supplemental Water—Based upon the foregoing considerations, it is concluded that the ground water units in the upper San Joaquin Valley requiring an imported supplemental water supply to meet the deficiencies in supply for present developed areas therein are those given in Table 142 and delineated on Plate LXVIII. The table sets forth the amount of average seasonal deficiency during the period 1921–1929 for each unit. The figures in the table for irrigated areas are for 1929, except those for the Kaweah and Tule-Deer Creek units, which are the average areas irrigated during the eight-year period 1921–1929.

TABLE 142

DEFICIENCIES IN WATER SUPPLY IN GROUND WATER UNITS IN UPPER SAN JOAQUIN VALLEY REQUIRING IMPORTED SUPPLIES

Ground water unit	Irrigated area, in acres	Average seasonal deficiency, 1921-1929, in acre-feet
Madera	81,000	61,000
Alta-Foothill	16,000	32,000
Kaweah	133,700	92,000
Lindsay	22,000	30,000
Tule-Deer Creek	67,400	56,000
Earlimart-Delano	30,500	50,000
McFarland-Shafter	49,800	61,000
Magunden-Edison	2,600	5,000
Totals	403,000	387,000

Lands under canal service of late priority in the Kings River area lying north of the Kings River along the valley trough and partially dependent upon ground water of considerable mineral content are omitted from the summary, but are included in the area for immediate relief in the allotment of imported water supplies as subsequently presented, not because of a shortage of water particularly, but because of the harmful quality of the ground water supply. These lands need an additional surface supply of fresh water for the restoration of soil conditions and relief of ground water draft.

The average total seasonal deficiency in supply for the period 1921–1929, as set forth in the summary, is estimated at 387,000 acre-feet. The maximum deficiency in one season was about 680,000 acre-feet in 1928–1929. The minimum seasonal deficiency was about 100,000 acre-feet in 1921–1922, excluding the figures for the Madera and Kaweah units which had a surplus in that season.

The provision of imported supplemental water supplies in amounts equal to the average seasonal deficiencies for each unit would meet the water requirements during a period of run-off the same as that of 1921–1929 and would result in ground water conditions the same at the end of the period as at the beginning thereof. However, if the run-off were more subnormal than that of the period 1921–1929, there would be a further lowering of ground water levels unless larger amounts of supplemental water supplies were imported. Looking ahead to the consummation of a plan of relief, it appears evident that the importation of supplemental water supplies sufficient only to meet the present average deficiencies would not be an adequate remedy for the areas of deficiency because it would not correct the present unfavorable conditions of excessive pumping lift. In addition to meeting present deficiencies, economic considerations point to the necessity of providing for replenishment of underground reservoirs and the reduction of present pumping lifts. Although local supplies would increase in amount with more normal run-off than during the period 1921–1929, the possibility of the occurrence of wet years can not be anticipated with certainty. It is desirable that plans for relief should provide for importation of supplemental water supplies sufficient in amount not only to meet the average deficiency based upon a subnormal period of run-off such as 1921–1929 but also to furnish additional water sufficient in amount to provide with certainty for substantial ground water replenishment. Furthermore it might be desirable and economical to provide for supplemental supplies in those areas not classed as ones of permanent deficiency, as for example the Fresno-Consolidated and Alta units. Therefore, to meet the deficiency in supply and to provide for ground water replenishment, it is estimated that average seasonal importations of supplemental water amounting to from 500,000 to 600,000 acre-feet should be provided as a minimum requirement.

Progressive Steps in Plan for Initial Development.

The plan for initial development in the San Joaquin River Basin has been considered in two steps:

First—A plan of development which would provide an average seasonal supplemental supply to the upper San Joaquin Valley of 500,000 to 600,000 acre-feet during the period 1921–1929, which is considered to be the minimum amount of supplemental water supply which would adequately meet the needs of present developed areas. This first step in the initial development has been designated as the "immediate initial" development.

Second—A plan of development which would furnish a greater amount of supplemental water supply than the minimum amount considered necessary in the "immediate initial" development, and which would provide with greater certainty for the complete relief of present developed areas in the upper San Joaquin Valley, for more substantial ground water replenishment and for expansion of irrigated areas on lands adjacent to present developments in accord with reasonable anticipations of growth in the near future. This second step in initial development has been designated as the "complete initial" development.

For the first step designated the "immediate initial" development, supplemental water supplies in the amount required as a minimum for present developed areas in the upper San Joaquin Valley could be obtained, as studies subsequently presented will show, either from the San Joaquin River alone by regulation of surplus water and water now put to inferior use on this stream, or from the combined sources of surplus water regulated on the San Joaquin River and water imported from Sacramento River Basin sources.

For the "complete initial" development however, imported supplemental water supplies would be required from the Sacramento River Basin because it is the only dependable source of surplus water adequate in amount during a subnormal period of run-off such as 1917–1929 to provide the amount of supplemental water supply required for complete initial development.

In the following portion of this chapter, consideration is given first to alternate plans for "immediate initial" development followed by the presentation of plans for a "complete initial" development.

Alternate Sources of Supplemental Water Supply and Plans for Immediate Initial Development.

In the formulation of a plan to furnish the foregoing estimated average seasonal supplemental supply of 500,000 to 600,000 acre-feet required to meet the deficiencies and to provide for ground water replenishment in the developed areas in need of immediate relief in the upper San Joaquin Valley, many alternative plans have been investigated and studied. These studies have involved estimates of water yield from various sources, estimates of cost and economic analyses of cost of supplemental water supplies delivered to the land.

The following sources of supplemental supply and plans for obtaining the same were investigated:

1. Surplus waters of east side tributaries of the lower San Joaquin River.
2. Development and regulation of local surface supplies on major streams of upper San Joaquin Valley.
3. Supply from San Joaquin River obtained by means of exchange for water imported from Sacramento River Basin.
4. Supply from San Joaquin River obtained from surplus waters and by purchase of "grass land" rights along San Joaquin River.

Inquiry was made as to the possibility and feasibility of obtaining a supply from the surplus waters of the east side tributaries of the lower San Joaquin River. After a study of the conditions on these streams, it appeared evident that it would not be feasible to export water from those sources because all existing surplus water on these streams is a part of the present supply for salinity control and consumptive use in the San Joaquin Delta. Furthermore, such amounts of surplus water now existing on these streams as could be made available for use in other localities by the substitution of a new water supply in the San Joaquin Delta would be required ultimately for the irrigation of the undeveloped lands in the lower San Joaquin Valley. Therefore, further consideration was not given to the possibility of obtaining a supply from those sources.

Study was given to the possible further development and regulation of the local water supplies of major streams in the upper San Joaquin Valley as contemplated under the plan for ultimate development. Utilizable water supplies in addition to the amounts now available without surface storage regulation could be obtained on the average over a long period of years from the Kern, Tule, Kaweah and Kings rivers by the construction of surface storage reservoirs on those streams, operated in combination with underground storage and pumping. However, a detailed study of the water supplies for the critical period 1917–1929 shows that the utilizable supply which could have been made available during that period by provision of surface storage regulation would be increased only a relatively small amount on Kings River; and, on the other three streams, would not be increased but, on the contrary, would be decreased because of reservoir evaporation. Table 143 shows the average seasonal amounts and the costs per acre-foot of new utilizable yield which could have been made available by surface storage regulation on these streams, both for the 40-year period 1889–1929 and for the shorter period 1917–1929. The total new utilizable yield from the four local sources practicable of development is 433,000 acre-feet per season, on the average, for the 40-year period 1889–1929 and only 45,000 acre-feet for the 12-year period 1917–1929. During the shorter period, no new water could have been developed for utilization on the Kern, Tule and Kaweah rivers and only 50,000 acre-feet per season on the average on Kings River. Based on the average

TABLE 143

AMOUNTS AND COSTS OF NEW UTILIZABLE YIELD BY SURFACE STORAGE REGULATION ON LOCAL MAJOR STREAMS IN UPPER SAN JOAQUIN VALLEY

Stream	Reservoir	Capacity of reservoir, in acre-feet	Seasonal new utilizable yield, in acre-feet		Cost per acre-foot of new utilizable yield			
					For period, 1889-1929		For period, 1917-1929	
			Average for period, 1889-1929	Average for period, 1917-1929	Capital	Annual	Capital	Annual
Kern River	Isabella	338,000	58,000	−1,000	$98 28	$5 86		
Tule River	Pleasant Valley	39,000	26,000	−3,000	111 54	6 58		
Kaweah River	Ward	100,000	43,000	−1,000	188 37	11 33		
Kings River	Pine Flat	400,000	306,000	50,000	31 37	1 88	$192 00	$11 48
Totals		877,000	433,000	45,000				

new utilizable yield for the 40-year period 1889–1929, the capital cost per acre-foot of new water ranges from $31.37 for the Kings River to $188.37 for the Kaweah River. For the 12-year period 1917–1929, the capital cost for the Kings River is $192.00 per acre-foot. The annual costs per acre-foot range from $1.88 for the Kings River to $11.33 for the Kaweah River, based on the 40-year period. Based on the 12-year period, the annual cost for the Kings River is $11.48.

In evolving the plan for the ultimate development of the Great Central Valley, including the upper San Joaquin Valley, the water supply studies were based on the run-off of the streams for the 40-year period 1889–1929 because the run-off for this period was considered to be representative of the probable water supply that might be expected over a long period of years and it was concluded that it was proper that such a long period should be considered in analysis for the estimation of the yield of the reservoirs, both surface and underground. For the plan of immediate development in the upper San Joaquin Valley, on the other hand, it was concluded that the period 1917–1929, a period of subnormal run-off, should be used as the basis of water supply studies because an emargency exists in that area which demands immediate attention and relief; and therefore, regardless of the run-off character of the seasons of the immediate future, the water supply should be estimated on the basis of a dry period of record. Hence, in comparing available amounts and unit costs of supplemental water supplies from the several alternate sources considered, the run-off of each stream for the 12-year period 1917–1929 has been used instead of that for the 40-year period 1889–1929 as the basis of water supply. With the foregoing criteria as a guide, it may be seen that the amount of new utilizable water obtainable by surface storage development on the four major streams of the upper San Joaquin Valley south of the San Joaquin River is less than one-tenth of that required to meet the needs of the irrigated areas in distress in that region. Furthermore, the utilizable supply would be entirely from the Kings River. The annual cost of the new utilizable yield from this source would be $11.48 per acre-foot at the dam, including no costs for conveyance to areas of use. It will be shown in a later discussion that this figure exceeds the cost of water from other sources. Under a great number of diversion rights, Kings River water is used now to irrigate more than a half million acres of highly developed lands which are experiencing a temporary deficiency in surface supplies. It would appear, therefore, to be infeasible and probably legally impracticable to divert any water from the Kings River for use on other areas. Due to these conditions it is concluded that surface storage development and regulation of local surface water supplies on the four major streams of the upper San Joaquin Valley would not solve the problem of immediate relief.

Two other sources of supplemental supply were investigated. One is Sacramento River and other waters tributary to the Sacramento-San Joaquin Delta and the other is the surplus and "grass land" waters in the San Joaquin River. The use of water from the San Joaquin River alone or from the San Joaquin and Sacramento rivers combined, as a source of supplemental water supply for importation into the areas of deficiency in the upper San Joaquin Valley, involves units for initial development of the State Water Plan in the Sacramento River Basin which would be required to provide for immediate requirements in the

Sacramento River Basin as well as required supplemental water supplies for the San Joaquin River Basin. As previously stated, the use of existing surplus water supplies from the San Joaquin River which are now available to the Sacramento-San Joaquin Delta would require the replacement in the delta of such supplies by Sacramento River water. Moreover, although the amount of water that will be subsequently shown could be made available from regulation of surplus waters and waters now put to inferior use on the San Joaquin River probably would provide an adequate supply to satisfy the immediate needs for supplemental water in the upper San Joaquin Valley, it could not be certain in the future that there will not be seasons or periods of run-off even more subnormal than during the period 1917–1929 on which water supply studies have been based. Water in addition to the amounts that could be made available from the San Joaquin River from existing surpluses and water now put to inferior use may be required to meet the needs of present developed areas and provide for adequate ground water replenishment. Furthermore, it appears proper that some provision in the plan should be made for expansion of irrigated areas on lands adjacent to present developments which may be reasonably anticipated in the future. Therefore, provision should be made for exportation of supplemental water supplies from the Sacramento River Basin in order to make available a full and dependable water supply which will completely and adequately meet the immediate future needs of the upper San Joaquin Valley. In addition to the supplemental water supplies required from Sacramento River Basin for completely and adequately meeting the needs of the upper San Joaquin Valley, the requirements of the San Joaquin Delta region in the lower end of the San Joaquin River Basin must be supplied under initial development from Sacramento River sources. Whether or not water is exported from Sacramento River Basin sources to the San Joaquin Valley, the requirements of the San Joaquin Delta and adjacent uplands, together with the Sacramento Delta, would be supplied under the plan of initial development from the Sacramento River Basin. Under the proposed initial plan of development, regulated supplies would be released from the initial storage unit, Kennett Reservoir on the Sacramento River, to supplement the unregulated inflow into the delta from both the Sacramento and San Joaquin river systems to provide a full supply for the consumptive needs of the delta and adjacent upland areas and to maintain fresh water at all times in the delta channels by controlling saline invasion from the bay at the lower end of the delta. The supply furnished would provide for the replacement of any surplus water of the San Joaquin River now available to the delta which the initial plan of development would divert for use in the upper San Joaquin Valley.

The controlling elements governing the selection of a plan of immediate initial development for the upper San Joaquin Valley are:

1. The quantity and characteristics of water supply to be secured thereby.
2. The cost of water, delivered to the land.
3. The degree of provision for expansion by enlargement and extension, as may be required, in accordance with the provisions of the complete initial and ultimate plans of development.

Alternate Plans Investigated. Many plans have been studied and analyzed for importing supplemental water supplies from San Joaquin and Sacramento river sources into the areas of deficiency in the upper San Joaquin Valley for an immediate initial development. Of these, six have been chosen for presentation. Two plans, Nos. I and II, would import water from the Sacramento-San Joaquin Delta in combination with regulation and utilization of San Joaquin River water. Four plans, Nos. III, IV, V and VI, would utilize certain surplus and "grass land" waters of the San Joaquin River. In all of these plans, it is assumed that adequate storage would be provided in the Sacramento River Basin, and operated to provide the water requirements for consumptive use and control of saline invasion in the Sacramento-San Joaquin Delta; and, in the case of Plans Nos. I and II, to provide adequate additional supplies in the delta for exportation to the San Joaquin Valley. In the financial comparison of the six plans, no costs are included for the Sacramento River Basin storage, which would be required to be constructed before exportation from the delta could be effected. Also, it is assumed that such storage necessarily must be constructed and operated for salinity control and consumptive use requirements in the delta before any exportation of surplus and "grass land" water would be permitted from the upper San Joaquin River.

A brief description and an enumeration of the units included in the six alternate plans considered for immediate initial development are given in the following paragraphs. The data briefly summarized herewith are based upon detailed month by month studies of water supply and operation of the units, cost estimates of all units of each plan, and cost of delivery and utilization of water.

Plan I

The units included in Plan I are as follows:

1. Sacramento-San Joaquin Delta Cross Channel.
2. San Joaquin River Pumping System—capacity, 3000 second-feet.
3. Friant Reservoir—gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
4. Madera Canal—capacity, 1500 second-feet.
5. San Joaquin River-Kern County Canal—capacity, 3000 second-feet, San Joaquin River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek; 1500 second-feet, Poso Creek to Kern River.
6. Magunden-Edison Pumping System—capacity, 20 second-feet.

In this plan, the Friant Reservoir, Madera Canal and San Joaquin River-Kern County Canal to Kern River, would be constructed to ultimate capacities and the San Joaquin River Pumping System to the capacity required for complete initial development. Under this plan, the "grass land" rights on the San Joaquin would not be purchased. With this plan in operation, portions of the irrigated areas, both crop and grass lands now served by San Joaquin River water in the lower San Joaquin Valley, would be furnished with an imported water supply by means of the San Joaquin River Pumping System in substitution for water diverted at Friant to the upper San Joaquin Valley, except during periods when there would be excess waters passing Friant dam. The areas of deficiency in the upper San Joaquin Valley would be furnished a full supplemental water supply from Friant Reservoir in accord with the irrigation demand in the amount of 602,000 acre-feet each season, based upon the run-off for the period 1917–1929. The lands now under irrigation along the San Joaquin River above Mendota would be furnished a supply from the Friant Reservoir. The works proposed under this plan would permit the diversion of the entire San Joaquin River at Friant, if the "grass land" rights, on the San Joaquin River above the Merced River, should be purchased, thus making it the same as the plan for "complete initial" development subsequently presented. In estimating the cost of the plan, one-half of the cost of the Sacramento-San Joaquin Delta Cross Channel and a sum of $1,000,000 for general expense and water rights are included.

Plan II

The units included in Plan II are as follows:

1. Sacramento-San Joaquin Delta Cross Channel.
2. San Joaquin River Pumping System—capacity, 1000 second-feet.
3. Friant Reservoir—gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
4. Madera Canal—capacity, 1500 second-feet.
5. San Joaquin River-Kern County Canal—capacity, 3000 second-feet, San Joaquin River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek, 1500 second-feet, Poso Creek to Kern River.
6. Magunden-Edison Pumping System—capacity, 20 second-feet.

In this plan, the Friant Reservoir, Madera Canal, San Joaquin River-Kern County Canal and Magunden-Edison Pumping System would have the same respective capacities as under Plan I. The San Joaquin River Pumping System, however, would have a capacity of only 1000 second-feet to Los Banos and 500 second-feet to Mendota. As in Plan I, the "grass land" rights on the San Joaquin River would not be purchased. The supply for the "grass lands" would be furnished by the San Joaquin River Pumping System, making available for regulation at Friant Reservoir the water now used for this purpose. A seasonal irrigation supply of 604,000 acre-feet on the average would be made available based on the run-off for the period 1917–1929. This water, however, would not be in complete accord with the irrigation demand. The characteristics of the supply would be similar to those under Plan VI. A portion of the supply would be delivered outside the irrigation demand for utilization by underground storage and pumping. One-half the cost of the Sacramento-San Joaquin Delta Cross Channel and a sum of $1,000,000 for general expense and water rights, as under Plan I, are included in the cost estimates.

Plan III

The units included in the plan are as follows:

1. Friant Reservoir—gross capacity, 185,000 acre-feet and net capacity, 130,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
2. Madera Canal—Capacity, 500 second-feet.
3. San Joaquin River-Kings River Canal—capacity, 3000 second-feet on low line location, diverting at Friant at elevation 420 feet.
4. Pine Flat Reservoir—gross capacity, 200,000 acre-feet and net capacity, 140,000 acre-feet. Power plant, 34,500 kilovolt-amperes.
5. Kings River-Kern County Canal—capacity, 1000 second-feet, Kings River to Tule River; 750 second-feet, Tule River to Deer Creek; 500 second-feet, Deer Creek to Poso Creek.

Under this plan the "grass land" rights on the San Joaquin River would be purchased. The supplemental supply for the upper San Joaquin Valley would be obtained from that source and the existing surplus in the San Joaquin River at Friant. The San Joaquin River Pumping System is not included as part of this plan. Through the utilization of existing surplus water and water obtained by purchase of the "grass land" rights on San Joaquin River, an average yield of 485,000 acre-feet per season could have been obtained from those sources during the period 1917–1929. Of the water supply which could have been made available, 370,000 acre-feet or 76 per cent would have been in-season and 115,000 acre-feet or 24 per cent, out of season. Of the in-season water, there would have been 140,000 acre-feet of primary yield or 38 per cent in accord with the irrigation demand every season. The water furnished from Friant Reservoir through the San Joaquin River-Kings River Canal would be delivered to the Kings River area, replacing Kings River water now used thereon which would be diverted or stored in Pine Flat Reservoir for subsequent diversion through the Kings River-Kern County Canal serving the areas south of Kings River in the upper San Joaquin Valley. This exchange of supplies would be effected without disturbance of the present Kings River daily flow schedule of diversion rights. The lower diversion elevation from Friant Reservoir decreases the amount of dead storage and the amount of net storage capacity required but decreases the yield of electric energy from the power plant. This plan of lower diversion elevation from Friant Reservoir makes necessary the exchange of supplies at Kings River. The capacities of the Madera and Kings River-Kern County canals in this plan are fixed by the minimum initial delivery requirements. This plan differs from Plans I and II in that the importation canal from Kings River to Kern County terminates at Poso Creek. Therefore, no provision is made for the Magunden-Edison Pumping System. It is assumed that some arrangement would be made locally to supply this area by purchase of water rights now attached to inferior lands or otherwise. A sum of $5,000,000 is included in the cost estimate for the purchase of "grass land" water rights and for general expense.

Plan IV

The units included in this plan are as follows:

1. Friant Reservoir—gross capacity, 325,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
2. Madera Canal—capacity, 1500 second-feet.
3. San Joaquin River-Kings River Canal on low line location diverting at Friant at elevation 420 feet. Capacity, 4000 second-feet.
4. Pine Flat Reservoir—gross capacity, 400,000 acre-feet and net capacity, 340,000 acre-feet. Power plant, 40,000 kilo-volt-amperes.
5. Kings River-Kern County Canal—capacity, 3000 second-feet, Kings River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek; 1500 second-feet, Poso Creek to Kern River.
6. Magunden-Edison Pumping System—capacity, 20 second-feet.

This plan provides for exchange of water at Kings River as in Plan III. However, greater reservoir capacities are assumed at both Friant and Pine Flat and also larger canal capacities for the Madera, San Joaquin River-Kings River and Kings River-Kern County canals. This plan would effect accomplishments equivalent to those under Plan VI. ''Grass land'' water rights on the San Joaquin River would be purchased and the water therefrom with surplus supplies regulated by Friant Reservoir. The San Joaquin River Pumping System is not included in the plan. By this plan a greater amount of water would have been obtained than with Plan III. Based on the period 1917–1929, an average of 590,000 acre-feet per season could have been obtained from the ''grass land'' rights and surplus waters in the San Joaquin River, whereas the comparable figure under Plan III is 485,000 acre-feet. Of this amount, 74 per cent would have been in-season water and 26 per cent out of season. Of the in-season water, there would have been 140,000 acre-feet of primary yield or 32 per cent in accord with the irrigation demand every season. An amount of $5,000,000 is included in the estimates of cost for general expense and purchase of water rights.

Plan V

The units included in Plan V are as follows:

1. Friant Reservoir—Gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilo-volt-amperes.
2. Madera Canal—capacity, 500 second-feet.
3. San Joaquin River-Kern County Canal—capacity, 1000 second-feet, San Joaquin River to Tule River; 750 second-feet, Tule River to Deer Creek; 500 second-feet, Deer Creek to Poso Creek.

In this plan, the ''grass land'' water rights on the San Joaquin River would be purchased and water therefrom with surplus supplies regulated by Friant Reservoir which would be constructed to ultimate capacity. The Madera and the San Joaquin River-Kern County canals would be constructed to the minimum capacities sufficient to meet the immediate needs. There would be no provision for enlargement in the design of these units. The San Joaquin River-Kern County Canal would terminate at Poso Creek. This plan would serve all areas in immediate need except the Magunden-Edison unit in Kern County. The Magunden-Edison Pumping System would not be constructed. For the 12-year period 1917–1929, the amount of water that could have been supplied from the surplus and grass land waters of the San Joaquin River under this plan would have been 540,000 acre-feet per season on the average. Of this amount, 75 per cent would have been in-season and 25 per cent out of season water. Of the in-season water, there would have been 138,000 acre-feet of primary yield or 34 per cent in accord with the irrigation demand every season. A sum of $5,000,000 is included in the cost estimates to cover general expense and purchase of water rights.

Plan VI

The units included in this plan are as follows:

1. Friant Reservoir—gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
2. Madera Canal—capacity, 1500 second-feet.
3. San Joaquin River-Kern County Canal—capacity, 3000 second-feet, San Joaquin River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek; 1500 second-feet, Poso Creek to Kern River.
4. Magunden-Edison Pumping System—capacity, 20 second-feet.

In this plan, the "grass land" rights on the San Joaquin River would be purchased and the water therefrom with surplus supplies regulated by Friant Reservoir. All of the units would be constructed immediately to ultimate capacity. A foundation investment would be made so that future expansion in the upper San Joaquin Valley could take place when it appeared economically desirable.

Based on the 12-year period 1917–1929, 602,000 acre-feet of water per season on the average could have been obtained from the surplus and "grass land" waters of the San Joaquin River with the proposed units of this plan. Of this amount 80 per cent would have been in-season water and 20 per cent out of season water. Of the in-season water, there would have been 138,000 acre-feet of primary yield or 29 per cent in accord with the irrigation demand every season. A sum of $5,000,000 is included in the cost estimates to cover general expense and purchase of water rights.

Capacity of Friant Reservoir for Immediate Initial Development—The capacity of Friant Reservoir for immediate initial development is based upon a detailed month by month study of reservoir operation for the regulation of the water supply that would have been available from surplus waters and grass land rights on the San Joaquin River during the period 1917–1929 to furnish the required supplemental water supplies to the areas of deficiency in the upper San Joaquin Valley and provide the full requirements of present developed areas. The supplemental supplies furnished from Friant Reservoir combined with local supplies would be utilized through the combined means of surface diversion and ground water storage and pumping. The detailed studies of reservoir operation and required storage capacity for initial development were made in a similar manner as those presented for ultimate development in Chapter VI. The reservoir would be operated to deliver as large a surface irrigation supply as possible during the months of peak irrigation demand and in addition provide as much water as possible outside the irrigation season for ground water storage and subsequent pumping. As in the case of ultimate development, the fullest practicable utilization of the underground storage capacity in the upper San Joaquin Valley is essential in order to economically meet the full requirements of present developed areas with the water supplies that would be available. The underground reservoirs afford the only economical and feasible means of providing the cyclic storage required to effect a full utilization of water supplies available for meeting the present requirements.

Briefly summarized, the studies showed that, in order to regulate the available supply from surplus waters and grass land rights on the San Joaquin River during the period 1917–1929 to provide an average seasonal supplemental water supply of from 500,000 to 600,000 acre-feet during this period, a net storage in Friant Reservoir of 110,000 to 130,000 acre-feet would have been required, depending upon the capacity of the San Joaquin River-Kern County Canal. With a capacity of 3000 second-feet for this canal, the required net reservoir capacity would have been 110,000 acre-feet; with a capacity of 1000 acre-feet, 130,000 acre-feet; for approximately equal average seasonal yields of supplemental water. The supplemental supply furnished with these net reservoir capacities would consist largely of out of season water, the utilization of which would require ground water storage and pumping. The amount of in-season water would vary considerably from season to season and would not be sufficient for present needs particularly in nonabsorptive areas.

In order to supply the nonabsorptive areas with the same adequacy as the absorptive areas under a plan for initial development, it was concluded that a full surface irrigation supply should be provided each season in the amount required for the developed lands therein. The nonabsorptive areas would require a surface irrigation supply each season of about 107,000 acre-feet to fully meet the present requirements. In addition it was assumed that the Madera unit, because of rights to acquire San Joaquin River water initiated by the Madera Irrigation District, should be furnished with a surface irrigation supply each season with not less than 31,000 acre-feet in a season of minimum yield. Combining these two requirements for a surface irrigation supply each season designated as a primary irrigation supply, the studies showed that an additional net storage capacity of about 140,000 acre-feet would be required in Friant Reservoir. As stated in the studies presented under ultimate development, the provision of additional storage for obtaining this required amount of primary water supply would not materially increase the average seasonal yield from the reservoir. Based upon this requirement for primary surface irrigation supplies, th required net storage capacity of Friant Reservoir under initial development was determined to be 250,000 and 270,000 acre-feet, respectively, for canal capacities of the San Joaquin River-Kern County Canal of 3000 and 1000 second-feet. The criteria upon which these required net storage capacities in Friant Reservoir are based are particularly applicable to plans II, V and VI. In order to simplify the analyses and also in view of the fact that the net storage capacity of Friant Reservoir found to be required for both complete initial and ultimate development was 270,000 acre-feet, a net storage capacity of this amount was adopted as a basis for estimating the cost and water supply yield of Friant Reservoir under these three plans.

Under Plan I, the same storage capacity was adopted but the water supply considered available for regulation under this plan is larger in amount as it includes some San Joaquin River waters now used on crop lands which would be replaced by waters conveyed through the San Joaquin River Pumping System. Moreover, Plan I differs from plans II, V and VI in that the reservoir was operated to provide a primary surface irrigation supply each year of over 600,000 acre-feet.

Under plans III and IV the capacity of Friant Reservoir is governed to some extent by the proposed plan of exchange on Kings River with storage in Pine Flat Reservoir which involves a different plan of operation for Friant Reservoir than in plans II, V and VI. However, a net storage capacity of 270,000 acre-feet in Friant Reservoir was found necessary under Plan IV to effect accomplishments comparable to plans II and VI.

Cost of Alternate Plans for Immediate Initial Development—Estimates of cost for the six alternate plans for obtaining a supplemental water supply for immediate initial development are presented in summary form in Tables 144 to 149, inclusive, and are consolidated in Table 150. The estimates of the respective plans are strictly comparable both as to type of construction and unit prices used. All estimates are based on the same types of construction as described in Chapter VI for the units of the ultimate State Water Plan. The estimates for the Friant and Pine Flat dams are based on gravity concrete sections, and those of the Madera, San Joaquin River-Kern County canals and canals of the San Joaquin River Pumping System on concrete lined sections. The estimates for the San Joaquin River Pumping System are based on the same type of dams and pumping plants as shown on Plate LVIII. Unit prices for Friant and Pine Flat dams are the same as set forth in Table 66, those of the San Joaquin River Pumping System the same as in Table 105 and those of the Madera and San Joaquin River-Kern County canals the same as in Table 108. The unit prices of construction, set forth in the tables above referred to, are for the items in place and are exclusive of amounts for administration, engineering, contingencies and interest during construction. To each cost estimate there has been added 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction at 4.5 per cent, computed on a basis of financing at the beginning of each six months and compounding to the end of the construction period. Annual costs including those for interest and amortization on bonds, depreciation, operation and maintenance have been estimated for each unit. Annual electric energy costs have been estimated for conveyance units having pumping plants. The bases for estimating annual costs are the same as set forth in Chapter VI for storage and conveyance units of the ultimate State Water Plan.

The investment in the Friant power plant is assumed to be amortized in 10 years because, with further possible expansion of irrigation in the upper San Joaquin Valley, the San Joaquin River Pumping System would be installed, and ultimately the entire flow practicable of being utilized would be diverted above the plant.

The values of the electric energy at the power plants of the Friant and Pine Flat reservoirs are based on the cost of producing an equivalent amount of electric energy of the same characteristics with a steam-electric plant located in the area of consumption, taking into account the cost of transmission from point of generation to load centers. The electric energy charges for pumping in the San Joaquin River and Magunden-Edison pumping systems are in accord with the power schedules of the public utilities distributing power in the region in which the systems are located.

The total cost of supplemental water supply at the land under each plan was obtained by adding to the net annual cost at main canal side:

1. The average annual cost of surface distribution of in-season water. A figure has been used of $1.00 per acre-foot for all plans except Plan I. For the latter plan it is assumed that the main distributaries would be concrete lined. This would result in an additional annual cost of $0.25 per acre-foot but would reduce the conveyance losses and pumping installation for reuse. The supply under Plan I is in accord with the irrigation demand every season.

2. The average annual cost of surface distribution of out of season water. This cost is estimated at $0.15 per acre-foot. The cost of operation and maintenance only is included because the same canals would be used for distributing this water as for the in-season water. No charges are included for cost of releasing out of season water into natural channels as it is believed the operation and maintenance charges included in the annual costs of the main canal are adequate to cover any possible costs of such operation.

3. The average annual energy charge for pumping the portion of the supplemental water supply utilized by underground storage and pumping. The unit cost used in the estimates is $0.03 per acre-foot per foot of lift. The total energy charge is calculated on an estimated average lift of 63 feet, including well drawn down, for the absorptive areas of permanent deficiency and the average annual amount which would have been pumped during the 12-year period 1917–1929. The estimated average lift of 63 feet is a weighted average for all areas of deficiency based upon the records of ground water levels during the period 1921–1929. The average gross amount of water pumped is estimated at 125 per cent of the water made available from supplemental supplies for ground water pumping. This factor is based on the assumption that the water

pumped from underground would be applied at a gross rate of 2.5 acre-feet per acre or 25 per cent in excess of the net use requirement. Hence, the energy charges involved in the utilization of water made available for ground water pumping would be based upon the pumping of 125 per cent of the ground water supply for a net use requirement of 2.0 acre-feet per acre. The amount of supplemental water made available for ground water pumping would comprise all the out-of-season water and the amounts of in-season water applied in excess of net use. Under Plan I, with main distributaries concrete lined, the gross application of in-season water is assumed to be at the rate of 2.5 acre-feet per acre. Hence, one-fifth of the gross application would be in excess of net use and would be absorbed underground. Under Plans II to VI inclusive with main distributaries unlined, the gross application of in-season water is assumed to be at the rate of 3 acre-feet per acre, one-third of which would be in excess of net use and would be absorbed underground. These amounts of gross application of in-season water in excess of net use would be utilized by ground water pumping in order to obtain the fullest practicable utilization of supplemental water supply furnished with a resulting net use of 2 acre-feet per acre.

4. The annual fixed charges on wells and pumping plants based on the installation required for a season of minimum ground water pumping. The unit cost used is $0.02 per acre-foot per foot of lift or $1.50 per acre-foot based on a maximum lift of 75 feet, including well draw down, representing a weighted average for all areas of deficiency for the season of lowest ground water levels during the period 1921–1929. The amount of water pumped in a season of maximum ground water pumping which would occur in a season of minimum yield of supplemental water supplies is based upon the assumption that the full net use requirements of the area to be served by supplemental water would be met by pumping from underground all of the supply required that would not be furnished by delivery of in-season water during that season. Under plans II to VI inclusive, the maximum gross amount of water pumped upon which fixed charges are based would be 125 per cent of the difference between the average seasonal supplemental water supply furnished for the entire period and two-thirds of the amount of in-season water actually delivered in the season of minimum yield. Under Plan I, the amount of water pumped would be the same each season.

TABLE 144

CAPITAL AND ANNUAL COSTS OF PLAN I FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply, 602,000 acre-feet of in-season water each season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping
Sacramento-San Joaquin Delta Cross Channel (one-half cost)	$2,000,000	$150,000
San Joaquin River Pumping System. Capacity 3,000 second-feet	15,000,000	1,266,000
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	14,000,900	840,000
Friant Power Plant—30,000 kilovolt amperes	1,500,000	222,000
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000
San Joaquin River-Kern County Canal. Maximum capacity 3,000 second-feet	27,300,000	2,225,000
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000
General expense and water rights	1,000,000	56,000
Totals	$63,400,000	$4,981,000
Annual costs to main canal side:		
Gross annual cost, exclusive of electric energy for pumping	$4,981,000	
Electric energy for pumping, 147,000,000 kilowatt hours at $0.0055 and 760,000 kilowatt hours at $0.012	818,000	
Gross annual cost, including electric energy for pumping	$5,799,000	$5,799,000
Revenues from sale of electric energy, 85,500,000 kilowatt hours at $0.0035		300,000
Net annual cost with deduction for power credit		$5,499,000
Total cost per acre-foot at main canal side		$9.14
Annual costs main canal side to land:		
Surface distribution of in-season water, 602,000 acre-feet at $1.25 per acre-foot	752,000	
Fixed charges on pumping installation for 150,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	225,000	
Energy charges for pumping 150,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	283,000	
Total annual cost main canal side to land	$1,260,000	1,260,000
Cost per acre-foot main canal side to land		$2.09
Total annual cost delivered to land		6,759,000
Total cost per acre-foot delivered to land		$11.23

TABLE 145

CAPITAL AND ANNUAL COSTS OF PLAN II FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply, 484,000 acre-feet of in-season water and 120,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Sacramento-San Joaquin Delta Cross Channel (one-half cost)	$2,000,000	$150,000	
San Joaquin River Pumping System. Capacity 1,000 second-feet	8,000,000	701,000	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	14,000,000	840,000	
Friant Power Plant—30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin River-Kern County Canal. Maximum capacity 3,000 second-feet	27,300,000	2,225,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
General expense and water rights	1,000,000	56,000	
Totals	$56,400,000	$4,416,000	
Annual costs to main canal side:			
Gross annual cost, exclusive of electric energy for pumping	$4,416,000		
Electric energy for pumping 114,400,000 kilowatt hours at $0.0055 and 760,000 kilowatt hours at $0.012	638,000		
Gross annual cost, including electric energy for pumping	$5,054,000	$5,054,000	
Revenues from sale of electric energy, 105,000,000 kilowatt hours at $0.0035		367,000	
Net annual cost with deduction for power credit		$4,687,000	
Total cost per acre-foot at main canal side			$7.76
Annual costs main canal side to land:			
Surface distribution of in-season water 484,000 acre-feet at $1.00 per acre-foot	$484,000		
Surface distribution of out-of-season water 120,000 acre-feet at $0.15 per acre-foot	18,000		
Fixed charges on pumping installation for 488,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	732,000		
Energy charges for pumping 352,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	665,000		
Total annual cost main canal side to land	$1,899,000	$1,899,000	
Cost per acre-foot			$3.14
Total annual cost delivered to land		6,586,000	
Total cost per acre-foot delivered to land			$10.90

TABLE 146

CAPITAL AND ANNUAL COSTS OF PLAN III FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 370,000 acre-feet of in-season water and 115,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost	
Friant Reservoir. Gross capacity 185,000 acre-feet. Net capacity 130,000 acre-feet	$6,500,000	$390,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 500 second-feet	1,500,000	123,000	
San Joaquin-Kings River Low Line Canal. Capacity 3,000 second-feet	5,500,000	448,000	
Pine Flat Reservoir. Gross capacity 200,000 acre-feet. Net 140,000 acre-feet	6,000,000	360,000	
Pine Flat Power Plant. Capacity 34,500 kilovolt-amperes	1,700,000	145,000	
Kings River-Kern County Canal. Maximum capacity 1,000 second-feet	10,800,000	880,000	
General expense and water rights	5,000,000	278,000	
Totals	$38,500,000	$2,846,000	
Annual costs to main canal side:			
Gross annual cost		$2,846,000	
Revenues from sale of electric energy, 90,000,000 kilowatt hours at $0.0035 and 100,000,000 kilowatt hours at $0.0030		615,000	
Net annual cost with deduction for power credit		$2,231,000	
Total cost per acre-foot at main canal side			$4.60
Annual costs main canal side to land:			
Surface distribution of in-season water 370,000 acre-feet at $1.00 per acre-foot	$370,000		
Surface distribution of out-of-season water 115,000 acre-feet at $0.15 per acre-foot	17,000		
Fixed charges on pumping installation for 490,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	735,000		
Energy charges for pumping 298,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	563,000		
Total annual cost main canal side to land	$1,685,000	$1,685,000	
Cost per acre-foot main canal side to land			$3.47
Total annual cost delivered to land		3,916,000	
Total cost per acre-foot delivered to land			$8.07

TABLE 147

CAPITAL AND ANNUAL COSTS OF PLAN IV FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 434,000 acre-feet of in-season water and 156,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Friant Reservoir. Gross capacity 325,000 acre-feet. Net capacity 270,000 acre-feet	$11,100,000	$666,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin-Kings River Low Line Canal. Capacity 4,000 second-feet	6,600,000	538,000	
Pine Flat Reservoir. Gross capacity 400,000 acre-feet. Net capacity 340,000 acre-feet	9,600,000	574,000	
Pine Flat Power Plant. Capacity 40,000 kilovolt amperes	2,000,000	168,000	
Kings River-Kern County Canal. Maximum capacity 3,000 second-feet	19,500,000	1,590,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
General expense and water rights	5,000,000	278,000	
Totals	$57,900,000	$4,258,000	
Annual costs to main canal side:			
Gross annual cost exclusive of electric energy for pumping	$4,258,000		
Electric energy for pumping. 760,000 kilowatt hours at $0.012 per kilowatt hour	9,000		
Gross annual cost, including electric energy for pumping	$4,267,000	$4,267,000	
Revenues from sale of electric energy, 100,000,000 kilowatt hours at $0.0035 and 107,000,000 kilowatt hours at $0.0030 per kilowatt hour		671,000	
Net annual cost with deduction for power credit		$3,596,000	
Total cost per acre-foot at main canal side			$6.09
Annual costs main canal side to land:			
Surface distribution of in-season water 434,000 acre-feet at $1.00 per acre-foot	$434,000		
Surface distribution of out-of-season water 156,000 acre-feet at $0.15 per acre-foot	23,000		
Fixed charges on pumping installation for 621,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	931,000		
Energy charges for pumping 376,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	711,000		
Total annual cost main canal side to land	$2,099,000	$2,099,000	
Cost per acre-foot main canal side to land			$3.56
Total cost delivered to land		5,695,000	
Total cost per acre-foot delivered to land			$9.65

TABLE 148

CAPITAL AND ANNUAL COSTS OF PLAN V FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 407,000 acre-feet of in-season water and 133,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	$14,000,000	$840,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 500 second-feet	1,500,000	123,000	
San Joaquin River-Kern County Canal. Maximum capacity 1,000 second-feet	14,600,000	1,172,000	
Water rights and general expense	5,000,000	278,000	
Totals	$36,600,000	$2,635,000	
Annual costs to main canal side:			
Gross annual cost		$2,635,000	
Revenues from sale of electric energy 105,000,000 kilowatt hours at $0.0035		367,000	
Net annual cost with deduction for power credit		$2,268,000	
Total cost per acre-foot at main canal side			$4.20
Annual costs main canal side to land:			
Surface distribution of in-season water 407,000 acre-feet at $1.00 per acre-foot	$407,000		
Surface distribution of out-of-season water 133,000 acre-feet at $0.15 per acre-foot	20,000		
Fixed charges on pumping installation for 558,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	837,000		
Energy charges for pumping 336,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	635,000		
Total annual cost main canal side to land	$1,899,000	$1,899,000	
Cost per acre-foot main canal side to land			$3.52
Total annual cost delivered to land		4,167,000	
Total cost per acre-foot delivered to land			$7.72

TABLE 149

CAPITAL AND ANNUAL COSTS OF PLAN VI FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 481,000 acre-feet of in-season water and 121,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	$14,000,000	$840,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin River-Kern County Canal. Maximum capacity 3,000 second-feet	27,300,000	2,225,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
Water rights and general expense	5,000,000	278,000	
Totals	$50,400,000	$3,787,000	
Annual costs to main canal side:			
Gross annual cost exclusive of electric energy for pumping	$3,787,000		
Electric energy for pumping 760,000 kilowatt hours at $0.012	9,000		
Gross annual cost including electric energy for pumping	$3,796,000	$3,796,000	
Revenues from sale of electric energy 105,000,000 kilowatt hours at $0.0035		367,000	
Net annual cost with deduction for power credit		$3,429,000	
Total cost per acre-foot at main canal side			$5.70
Annual costs main canal side to land—			
Surface distribution of in-season water 481,000 acre-feet at $1.00 per acre foot	$481,000		
Surface distribution of out-of-season water 121,000 acre-feet at $0.15 per acre-foot	18,000		
Fixed charges on pumping installation for 635,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	952,000		
Energy charges for pumping 352,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	665,000		
Total annual cost main canal side to land	$2,116,000	$2,116,000	
Cost per acre-foot main canal side to land			$3.51
Total annual cost delivered to land		5,545,000	
Total cost per acre-foot delivered to land			$9.21

TABLE 150

SUMMARY OF CAPITAL AND ANNUAL COSTS OF SIX ALTERNATE PLANS FOR IMPORTING A SUPPLEMENTAL SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Plan	Capital cost	Average seasonal supplemental water supply for period 1917-1929, in acre-feet			Net annual cost at main canal side		Net annual cost at land	
		In-season	Out-of-season	Total	Total	Per acre-foot	Total	Per acre-foot
I	$63,400,000	602,000	0	602,000	$5,499,000	$9 14	$6,759,000	$11 23
II	56,400,000	484,000	120,000	604,000	4,687,000	7 76	6,586,000	10 90
III	38,500,000	370,000	115,000	485,000	2,231,000	4 60	3,916,000	8 07
IV	57,900,000	434,000	156,000	590,000	3,596,000	6 09	5,695,000	9 65
V	36,600,000	407,000	133,000	540,000	2,268,000	4 20	4,167,000	7 72
VI	50,400,000	481,000	121,000	602,000	3,429,000	5 70	5,545,000	9 21

The foregoing comparison of cost of supplemental water delivered to the land under the six alternate plans considered involves assumptions which are somewhat approximate as related to an actual plan of operation but, since the same approximations are made with respect to each alternate plan, the estimated costs per acre-foot of water delivered to the land are on a fair basis of comparison if due consideration be given to the accomplishments and scope of each plan which differ to some extent. Furthermore, consideration must be given to the fact that certain of the alternate plans do not permit of enlargement readily to meet the demands of ultimate development and, in some cases, even of complete initial development of the upper San Joaquin Valley.

Plan I is not strictly comparable with any of the other plans considered because it provides a supplemental water supply of over 600,000 acre-feet of in-season water in accord with the irrigation demand each season during the period 1917–1929, an entirely different provision than under any of the other plans considered. The result is a higher cost of water delivered to the land than in any of the other plans. It is presented to show how much greater the cost would be if it were considered necessary to furnish the entire amount of required supplemental water every season for utilization chiefly as a surface irrigation supply and with only a minimum amount of ground water pumping.

Plans II, IV and VI are very nearly comparable in accomplishments and scope and, of these, the studies show that Plan VI is the cheapest. If Plan VI were modified so as to terminate the San Joaquin River-Kern County Canal at Poso Creek, the capital cost would be reduced $2,357,000 and the annual cost $195,000. This would reduce the annual cost of water at main canal side to $5.37 per acre-foot and at the land to $8.89 per acre-foot. Moreover, Plan VI is the only one of these three which makes provision for future expansion of irrigation without additional expenditures for enlargement. The capacities of the units provided under Plan VI are the same as those found to be required for both complete initial and ultimate developments and no additional expenditures on these units would be required for future needs.

In Plan II, the San Joaquin River Pumping System would have a maximum capacity of 1000 second-feet as compared to a required capacity for complete initial development of 3000 second-feet. If provision were made in the design of this unit to allow for ready future enlargement, the cost under this plan would increase considerably.

In Plan IV, the units included are adequate to meet the demands for complete initial development but would not suffice for ultimate development. The plan would require modification. This could be accomplished by three possible methods, namely, first: Enlargement of Pine Flat Reservoir to a capacity of about 600,000 acre-feet; second: Enlargement of Friant Reservoir to a gross capacity of 400,000 acre-feet and relocation of the canal between San Joaquin and Kings rivers to the higher location selected for Plans V and VI; third: Importation of additional water from the Sacramento River Basin directly to the upper San Joaquin Valley.

Plans III and V are presented as representing what may be considered "minimum" projects for immediate relief. Neither of these plans make provision for future enlargement to meet the needs of ever complete initial development. In Plan III, no provision is made for the enlargement of the Friant and Pine Flat dams nor for the Madera and Kings River-Kern County Canal, and if such provision were made the cost would be substantially increased. Furthermore, the amount of supplemental water made available under Plan III is smaller than in any of the plans considered and is somewhat less than the minimum amount considered necessary to adequately meet requirements of an initial relief project.

Plan V, although appearing to be the cheapest of any of the plans in cost of water delivered to the land, makes no provision for future enlargement. If provision were made under this plan for initial construction of structures and other facilities which would permit of ready and economical enlargement of the San Joaquin River-Kern County Canal to the capacity required for complete initial development, the capital cost would be increased $5,277,000 and the annual cost $415,000, resulting in an annual cost of water delivered at main canal side of $4.97 per acre-foot and at the land of $8.49.

Plans III and IV differ from all of the other plans considered in one important particular, namely, the provision for exchange of water on Kings River. This plan of exchange was presented in a former report * based upon preliminary studies prior to the more complete investigations and data on which the present report is based. The foregoing economic analyses show that Plan III is greater in cost than the comparable alternate Plan V, and that Plan IV is greater in cost than the comparable alternate Plan VI. However, in addition to the greater cost of Plans III and IV than the alternate plans with comparable accomplishments, these plans also would involve important exchanges of water supplies on Kings River which would be difficult to effect and which are believed at this time to present an insurmountable obstacle in view of the schedule under which the waters of this stream are administered.

Selection of Plan for Immediate Initial Development—The selection of the most desirable plan for immediate initial development in the upper San Joaquin Valley is somewhat complicated because it necessarily involves the consideration of several physical and economic factors relating to future conditions or occurrence which are difficult to evaluate with certainty. The amount of water that would be available for regulation and utilization in future years is uncertain and must be based on past records. If there should occur a series of more subnormal years of run-off than that of the period used, 1917–1929, as a basis for estimating the water supply furnished under each plan, both local and supplemental supplies would be reduced in amount and the accomplishments of relief would be less adequate than estimated. The amount of water supply furnished under each plan involves not only the provision for meeting present deficiencies in water supply, but also and of equal importance the replenishment of the underground reservoirs to decrease pumping lifts and costs which are now excessive. The amount of expansion of irrigated agriculture in the upper San Joaquin Valley and the time at which such expansion may occur are also uncertain. However, studies of past growth and future

* Bulletin No. 9, "Supplemental Report on Water Resources of California—to the Legislature of 1925," Division of Engineering and Irrigation, 1925.

needs of irrigated agriculture in California point to a growth in irrigated agriculture in the future. Finally, it is uncertain by what methods and under what terms an immediate initial project would be financed, and especially what the interest rate and period of bond retirement would be. The cost analyses on the alternate plans were based upon an assumed interest rate of 4½ per cent and amortization of bonds in 40 years. The actual plan of financing effected would have considerable bearing on the choice to be made as between a minimum project for relief such as Plan V, designed to meet only the present needs, or a more adequate project of relief such as Plan VI which would provide with greater assurance for the present needs and allow for future expansion without additional expenditure on the units included therein.

Based upon the data and economic analyses presented with respect to the six alternate plans for immediate initial development and a consideration of present conditions of irrigation development in the upper San Joaquin Valley, the following conclusions are reached with respect to the most desirable plan for adoption.

1. Under Plan V, an adequate supplemental water supply, based upon the period of run-off 1917–1929 considered, could be furnished the 400,000 acres of developed land in need of immediate relief in the upper San Joaquin Valley, excluding the Magunden-Edison area of 2600 acres in Kern County, at a smaller cost than with any other plan investigated.

2. Considering the desirability of providing with greater assurance for adequate and dependable relief to the present developed areas and the reasonable probability of expansion of irrigated agriculture requiring additional water supplies in the future in the upper San Joaquin Valley; and in view of the greater flexibility of operation which would be obtained by the construction of units for immediate initial development of sufficient capacity to meet the needs under complete initial development; it is concluded that Plan VI is the most desirable and meritorious of all plans investigated for immediate initial development. The additional cost of this plan as compared to Plan V is more than balanced by its greater dependability and more assured adequacy for immediate relief and by its provision for probable future growth of irrigated agriculture in the upper San Joaquin Valley without additional expenditures on the units included in the plan.

3. If arrangements could be effected to purchase water rights on the Kern River now attached to inferior lands sufficient in amount to adequately serve the 2600 acres of developed land in the Magunden-Edison unit, the San Joaquin River-Kern County Canal could be terminated at Poso Creek in Kern County. In this manner, the cost of complete relief provided under Plan VI might be decreased. However, due to the present uncertainty of effecting such purchase of water rights, it is concluded that provision should be made for constructing the San Joaquin River-Kern County Canal to a terminus on Kern River in accord with Plan VI thereby insuring a water supply for the relief of the Magunden-Edison area, which would be provided by exchanging water delivered through the canal for Kern River water now used on lower areas served from this stream and thus permitting diversion of Kern River water to the Magunden-Edison unit.

Proposed Plan for Immediate Initial Development.

The plan designated as Plan VI has been selected for immediate initial development. It is the plan which, after careful study, appears to offer the greatest advantage and to be the most desirable for adoption from all viewpoints. The proposed physical units for immediate initial development comprise Friant Reservoir on the San Joaquin River (gross capacity 400,000 acre-feet), the Madera and San Joaquin River-Kern County canals extending northerly and southerly respectively from this reservoir with respective maximum capacities of 1500 and 3000 acre-feet, and the Magunden-Edison Pumping System (capacity 20 second-feet). It is proposed to acquire the "grass land" waters of the San Joaquin River with due consideration for existing rights that may be invaded in the process. Based upon the supplies available during the period 1917–1929, sufficient water would be obtained from this source and the surplus waters of the San Joaquin River, if regulated by surface storage in Friant Reservoir and by underground storage, to provide the supplemental supplies required in addition to available local supplies to meet the immediate needs of the developed areas of deficient water supply in the upper San Joaquin Valley.

The San Joaquin River Pumping System is not included in the immediate initial plan. It is proposed to defer construction of this unit until such time as additional water is found to be required to meet the needs in the upper San Joaquin Valley. The addition of this unit to those proposed for immediate development would complete the project designated as the "complete initial" development subsequently presented in this chapter. However, in setting up a plan of financing for initial development, it is believed that funds should be provided for this unit to insure adequate relief to the upper San Joaquin Valley. It is possible that the run-off occurring in future years might result in a succession of seasons more subnormal than experienced during the period 1917–1929 upon which the studies of water supply have been based. In this event, the amounts of utilizable water, from both local and supplemental sources of supply, that would be available under the proposed plan of immediate initial development might be so much less than the amounts estimated based on the period 1917–1929 that additional supplemental water supplies would be required to adequately meet the needs of present developed areas.* Such additional supplies would have to be obtained from the Sacramento River Basin and would require the construction of the San Joaquin River Pumping System to convey water from the delta to Mendota to supply crop lands in the lower San Joaquin Valley now served from the San Joaquin River, and thus make available more San Joaquin River Water for

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield under the immediate initial development have been extended to include the period 1929–1931 and are presented in Appendix D. These show that the average amounts of utilizable water supply from Friant Reservoir and from local sources in the upper San Joaquin Valley would be substantially less than those estimated for the period 1921–1929. Of particular importance, the studies showed that ground water replenishment would be inadequate and that present unfavorable conditions of excessive pumping lift and cost would not be permanently improved if a similar period of run-off such as 1921–1931 should be experienced immediately following 1931 and the project were in operation. These studies presented in Appendix D point to the possible necessity of including the San Joaquin River Pumping System in an immediate initial project if adequate relief including ground water replenishment is to be provided.

regulation in and distribution from Friant Reservoir for use in the upper San Joaquin Valley.

The general locations of the physical works both for immediate and complete initial development are shown on Plate XXVI. To further delineate the features of the initial plan, there is presented Plate LXIX, "Profile of Major Conveyance Units of State Plan for Initial Development in San Joaquin Valley. Sacramento-San Joaquin Delta to Kern County."

Operation and Accomplishments in Upper San Joaquin Valley—As in the plan for ultimate development, Friant Reservoir is the key unit in the plan of immediate initial development for the upper San Joaquin Valley. It would be operated primarily to furnish the required supplemental water supplies to meet the deficiencies in local supply for the present developed areas on the east side of the upper San Joaquin Valley, from the Madera unit on the north to the Magunden-Edison unit on the south. The supplemental supplies furnished from Friant Reservoir combined with local supplies would be utilized partly by direct surface diversion and application and partly by underground storage and pumping. The basis of operation and the amounts of water furnished from this reservoir under the plan of immediate initial development are set forth in the following discussion.

A study of the operation of Friant Reservoir under the plan of immediate initial development was made for the 40-year period 1889–1929. The impaired run-off of the San Joaquin River considered available at Friant Reservoir under the plan of immediate initial development was estimated on the assumption that the existing power storage reservoirs above Friant, with an aggregate capacity of 334,000 acre-feet, would have been operated primarily for power purposes during the entire 40-year period but without interference with the existing delivery schedule of crop land rights now served from the San Joaquin River in the lower San Joaquin Valley by diversion above the mouth of the Merced River. It was assumed that the first demand upon the flow of the San Joaquin River would be the supply for these crop lands in accord with the delivery schedule now under operation. The maximum seasonal total of the demand for these crop lands amounts to 895,700 acre-feet. The maximum monthly demands are shown in Table 151.

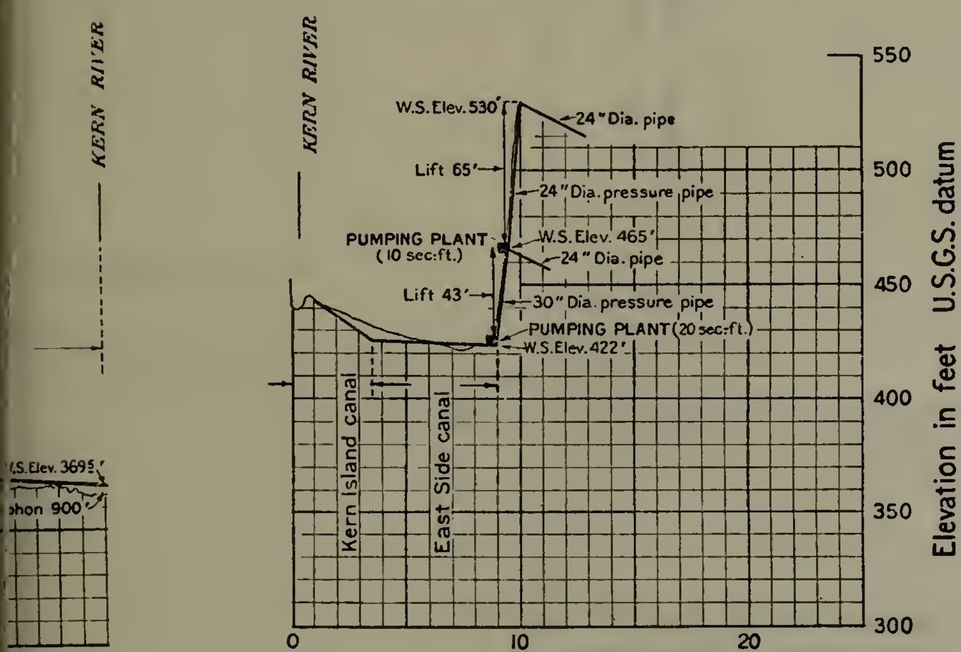
TABLE 151

MAXIMUM MONTHLY DEMAND OF WATER FOR IRRIGATION OF "CROP LANDS" SERVED FROM SAN JOAQUIN RIVER

Month	Maximum demand in acre-feet	Month	Maximum demand in acre-feet
October	27,900	April	114,700
November	8,400	May	158,700
December	6,400	June	163,000
January	10,000	July	142,000
February	27,900	August	108,300
March	51,600	September	76,800
Total			895,700

MAGUNDEN-EDISON PUMPING SYSTEM

Maximum capacity, 20 second-feet



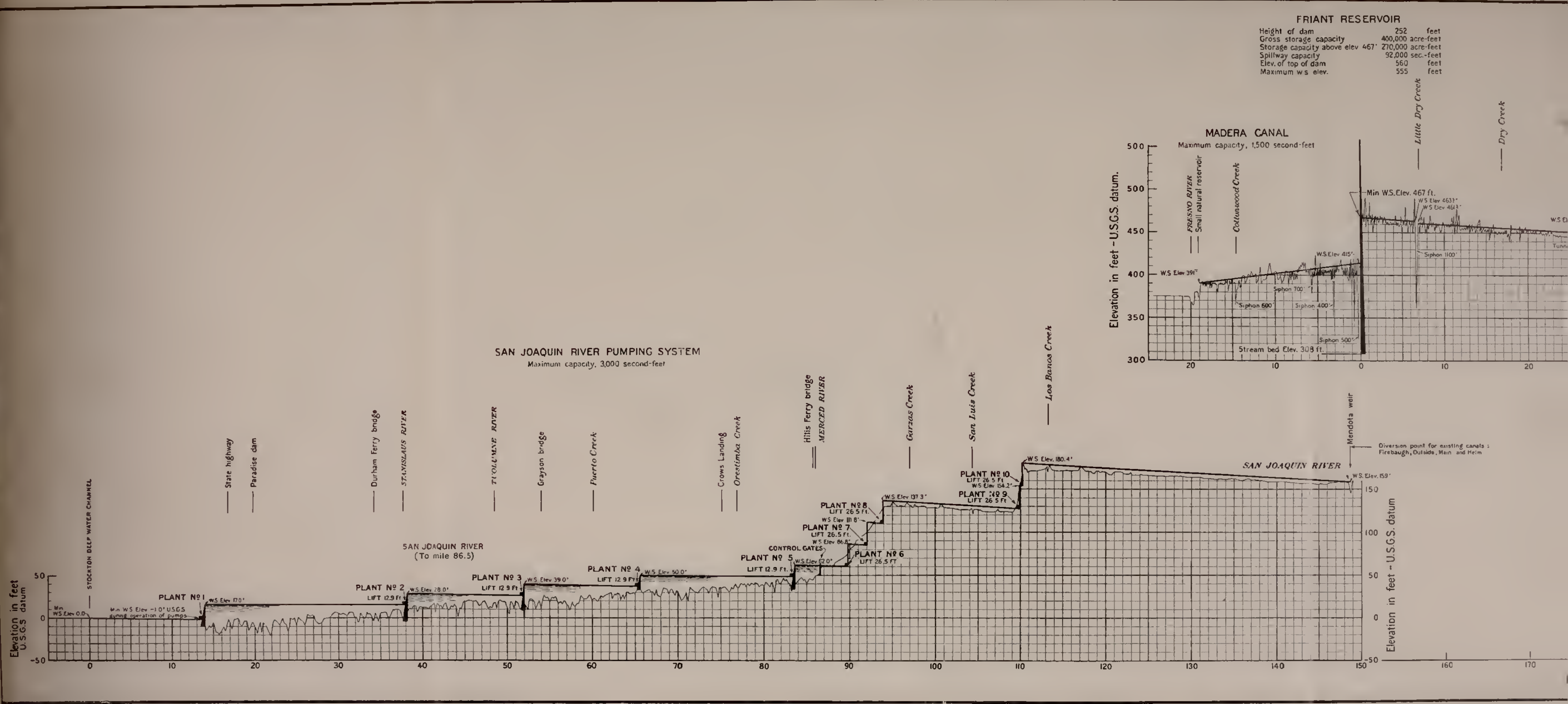
PROFILE OF

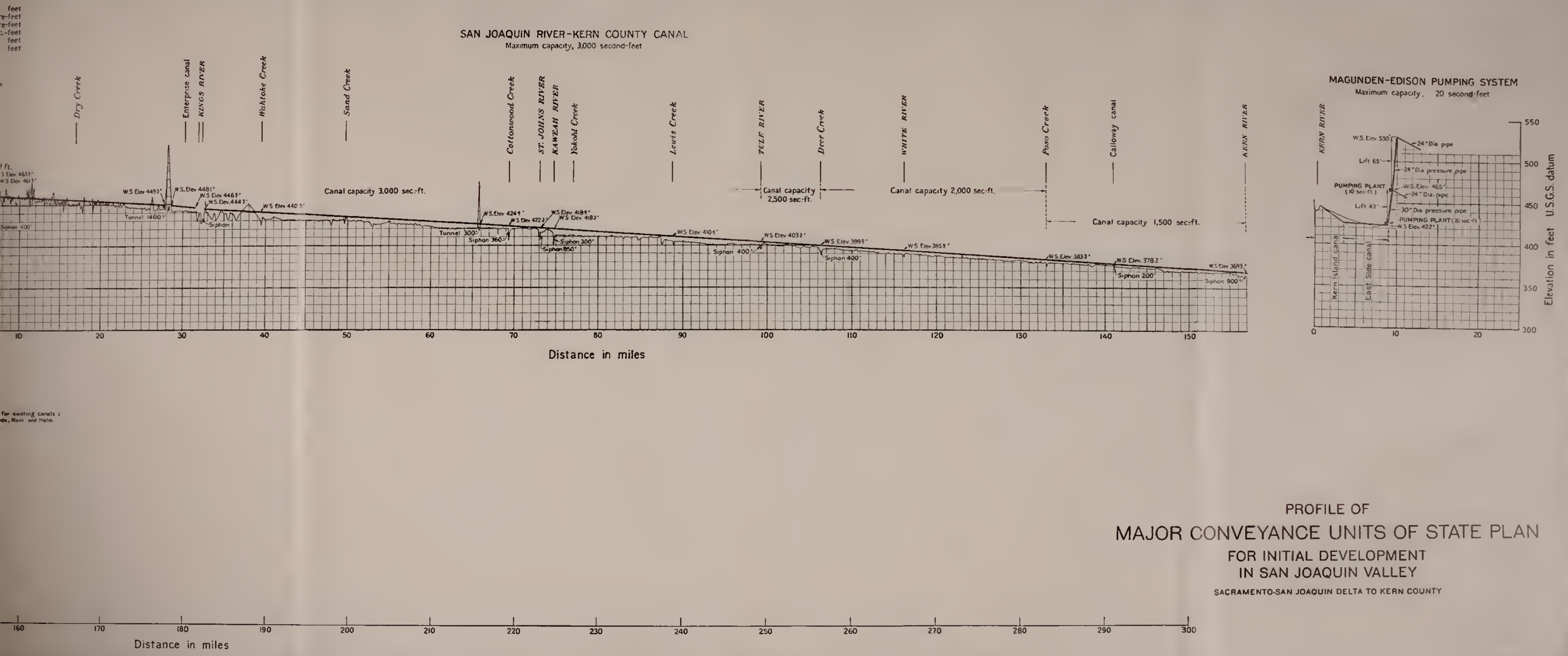
ONVEYANCE UNITS OF STATE PLAN

FOR INITIAL DEVELOPMENT

IN SAN JOAQUIN VALLEY

SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY


FRIANT RESERVOIR
Height of dam 252 feet
Gross storage capacity 400,000 acre-feet
Storage capacity above elev 467' 270,000 acre-feet
Spillway capacity 92,000 sec.-feet
Elev. of top of dam 560 feet
Maximum w.s elev. 555 feet
MADERA CANAL
Maximum capacity, 1,500 second-feet
Elevation in feet - U.S.G.S. datum
FRESNO RIVER
Small natural reservoir
Cottonwood Creek
Little Dry Creek
Dry Creek
Min W.S.Elev. 467 ft.
W.S Elev 391'
W.S.Elev 415'
Siphon 700'
Siphon 600'
Siphon 400'
Siphon 500'
Siphon 1100'
Stream bed Elev. 308 ft.
SAN JOAQUIN RIVER PUMPING SYSTEM
Maximum capacity, 3,000 second-feet
STOCKTON DEEP WATER CHANNEL
State highway
Paradise dam
Durham Ferry bridge
STANISLAUS RIVER
TUOLUMNE RIVER
Grayson bridge
Puerto Creek
Crows Landing
Orestimba Creek
Hills Ferry bridge
MERCED RIVER
Garzas Creek
San Luis Creek
Los Banos Creek
Mendota weir
Diversion point for existing canals : Firebaugh, Outside, Main and Helm
SAN JOAQUIN RIVER
W.S. Elev. 159'
W.S. Elev. 180.4'
PLANT Nº 10
LIFT 26.5 Ft.
W.S Elev 154.2'
PLANT Nº 9
LIFT 26.5 Ft.
W.S Elev 137.3'
PLANT Nº 8
LIFT 26.5 Ft.
W.S Elev 111.8'
PLANT Nº 7
LIFT 26.5 Ft.
W.S Elev 86.8'
PLANT Nº 6
LIFT 26.5 FT.
CONTROL GATES
PLANT Nº 5
LIFT 12.9 Ft.
W.S Elev 62.0'
PLANT Nº 4
LIFT 12.9 Ft.
W.S. Elev 50.0'
PLANT Nº 3
LIFT 12.9 Ft.
W.S. Elev 39.0'
PLANT Nº 2
LIFT 12.9 Ft.
W.S. Elev 28.0'
SAN JOAQUIN RIVER
(To mile 86.5)
PLANT Nº 1
W.S. Elev 17.0'
Min W.S. Elev 0.0
Min W.S. Elev -1.0' U.S.G.S. during operation of pumps
Elevation in feet U.S.G.S datum

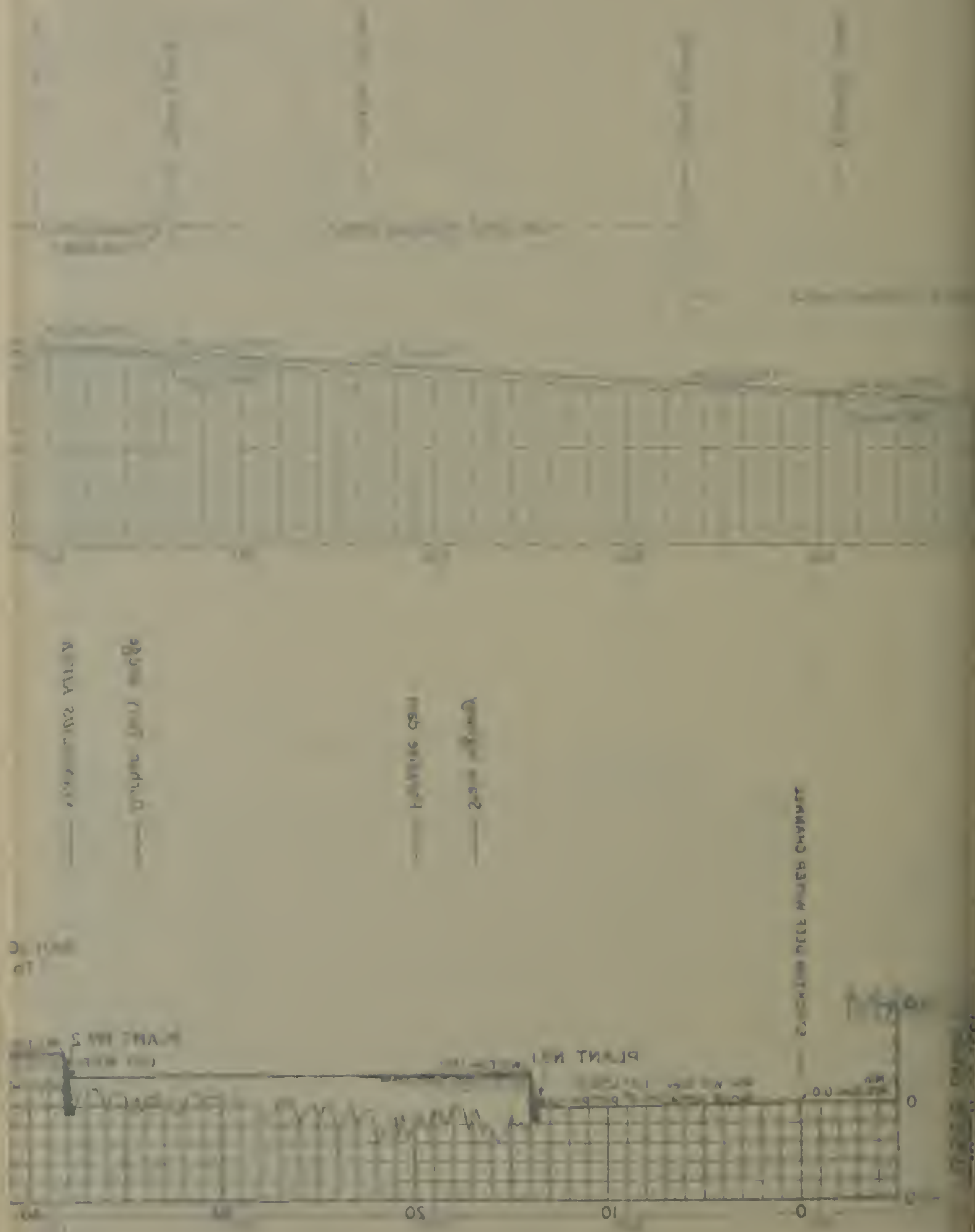


PROFILE OF

MAJOR CONVEYANCE UNITS OF STATE PLAN

FOR INITIAL DEVELOPMENT IN SAN JOAQUIN VALLEY

SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY



The remaining water supply after satisfying the crop land requirements, comprising surplus waters and waters not attached to areas now devoted to crop production but put to inferior use on grass lands, would be regulated in Friant Reservoir to furnish the supplemental supply required in the upper San Joaquin Valley. The amounts of water available for regulation and utilization from these grass land and surplus waters of the San Joaquin River are shown for each season of the period 1889–1929 in Table 152.

TABLE 152

GRASS LAND AND SURPLUS WATERS OF SAN JOAQUIN RIVER AVAILABLE FOR UTILIZATION UNDER PLAN OF IMMEDIATE INITIAL DEVELOPMENT IN UPPER SAN JOAQUIN VALLEY, 1889-1929

Quantities in Acre-feet

Season	October	November	December	January	February	March	April	May	June	July	August	September	Totals
1889–90	48,200	82,900	107,700	200,500	200,600	310,900	411,000	866,000	932,400	311,700	34,800	28,200	3,534,900
1890–91	62,700	76,400	86,400	131,700	117,200	152,600	182,100	285,700	309,800	93,500	0	4,900	1,503,000
1891–92	60,500	82,000	91,800	141,200	141,300	194,600	243,000	415,600	487,500	149,200	7,200	8,700	2,022,600
1892–93	59,600	80,100	89,500	142,600	134,600	182,800	227,700	369,200	444,500	133,200	4,800	7,600	1,876,200
1893–94	52,400	70,300	76,900	104,200	93,500	113,100	92,700	178,300	183,800	33,200	0	1,200	999,600
1894–95	55,500	58,900	105,400	165,000	135,000	139,900	178,500	453,800	389,900	143,200	7,100	21,800	1,854,000
1895–96	53,200	66,000	64,400	135,200	76,500	128,600	19,500	90,500	403,600	77,700	0	4,300	1,119,500
1896–97	44,100	76,100	75,500	61,700	116,500	107,400	218,900	487,700	148,300	19,600	0	0	1,355,800
1897–98	46,400	82,900	86,600	54,700	35,900	19,600	27,000	0	0	0	0	0	353,100
1898–99	21,100	21,000	20,600	17,000	4,200	102,700	88,600	24,300	92,300	0	0	0	391,800
1899–00	22,200	54,200	64,600	128,700	11,300	59,900	0	102,400	93,200	0	0	0	536,500
1900–01	31,200	111,000	77,000	192,100	230,000	222,200	149,200	338,700	492,400	78,700	46,100	7,700	1,976,300
1901–02	60,900	77,100	84,400	67,200	40,600	72,500	91,700	139,100	195,500	0	0	0	829,000
1902–03	44,000	65,600	61,100	72,600	44,200	58,000	48,200	267,000	230,400	0	0	0	891,100
1903–04	42,400	55,000	39,800	24,700	22,900	110,100	58,600	301,900	232,900	0	0	9,800	898,100
1904–05	105,300	74,500	63,700	62,200	61,200	104,900	33,700	112,400	127,700	0	0	0	745,600
1905–06	32,800	33,800	26,900	158,600	56,000	306,500	159,000	336,600	808,400	870,500	176,300	32,100	2,997,500
1906–07	63,500	64,800	81,600	121,300	116,000	251,600	259,100	279,700	416,400	335,700	26,700	12,600	2,029,000
1907–08	64,000	66,400	75,600	82,100	55,200	86,100	46,200	0	0	0	0	0	475,600
1908–09	29,100	30,600	29,400	235,400	152,300	100,000	206,800	322,600	588,100	172,800	3,300	7,100	1,877,500
1909–10	53,000	81,500	192,100	183,500	88,800	156,200	199,600	219,000	39,700	0	0	12,900	1,226,300
1910–11	53,000	64,700	72,900	221,900	186,800	290,600	272,900	278,100	712,800	451,600	18,600	16,200	2,640,100
1911–12	53,900	62,800	62,600	52,800	20,300	26,700	0	29,600	103,300	0	0	0	412,000
1912–13	20,000	38,700	27,400	21,500	7,200	0	0	28,900	0	0	0	0	143,700
1913–14	17,500	25,300	28,400	239,700	135,000	191,600	238,300	304,900	353,400	250,700	29,200	13,700	1,827,700
1914–15	57,300	60,800	63,300	65,400	83,400	92,800	109,700	141,100	318,200	119,000	0	5,200	1,116,200
1915–16	43,800	55,200	69,200	170,500	129,000	291,600	302,600	286,500	364,000	145,400	3,800	2,300	1,863,900
1916–17	69,600	67,400	75,200	68,500	121,600	74,700	79,500	127,100	313,800	74,300	0	0	1,071,700
1917–18	44,400	55,400	53,800	24,600	22,900	110,000	43,100	91,800	227,800	0	0	8,100	681,900
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	634,600

1919-20	13,200	20,200	33,100	22,500	6,200	51,300	32,900	186,100	91,500	0	0	0	457,000
1920-21	29,300	57,100	42,200	58,500	55,400	117,600	52,100	121,400	154,100	1,700	0	0	689,400
1921-22	42,400	45,300	61,800	61,200	71,900	59,400	64,900	379,100	476,100	125,300	0	0	1,387,400
1922-23	42,400	65,200	114,600	83,300	52,200	64,400	65,500	214,100	61,400	31,900	0	1,600	796,600
1923-24	54,300	57,800	59,100	22,000	0	0	0	0	0	0	0	0	193,200
1924-25	0	17,700	21,700	14,600	47,700	33,000	60,900	154,500	62,300	0	0	0	412,400
1925-26	44,700	44,000	50,200	18,200	32,300	46,300	161,900	97,500	0	0	0	0	495,100
1926-27	13,100	57,000	48,700	49,200	125,600	99,400	123,000	234,900	216,900	39,100	0	0	1,006,900
1927-28	48,200	90,200	74,200	49,600	31,700	72,500	35,900	87,700	0	0	0	0	490,000
1928-29	22,700	32,100	34,700	20,400	400	5,900	0	31,900	0	0	0	0	148,100
Averages, 1889-1929	45,400	59,700	68,400	94,900	77,700	116,400	116,400	214,700	251,800	91,500	8,900	5,200	1,149,000

With the available supply from surplus and grass land waters, Friant Reservoir would be operated in general to deliver as large a supply as possible during the months of peak irrigation demand for utilization by direct surface application in accord with coincident irrigation needs and for underground storage if in excess of irrigation needs; and in addition provide as much water as possible outside the irrigation season for ground water storage and subsequent pumping. The characteristics of the supply available for regulation would not permit of furnishing the full amount of 500,000 to 600,000 acre-feet of required supplemental water as a surface irrigation supply for direct application. In order to effect the fullest practicable utilization of the available supplies and provide adequately for meeting the immediate water requirements, the storage of water in underground reservoirs and subsequent utilization by pumping are essential. Therefore, the underground storage capacity in the absorptive areas would have to be fully utilized as being the only means of obtaining the large cyclic storage capacity required to regulate the extremely variable amounts of the supplemental water supplies obtained from the San Joaquin River and to regulate the local supplies as well.

However, there are certain nonabsorptive areas with a deficient water supply in the upper San Joaquin Valley for which ground wate storage and pumping would not be a practicable means of providing th required supplies. These are typified by such areas as the Alta-Foot hill, Lindsay and Magunden-Edison units. In order to supply thes nonabsorptive areas with the same adequacy as the absorptive areas, a primary surface irrigation supply in accord with the irrigation deman would have to be provided each season in the full amount required For the nonabsorptive areas south of the San Joaquin River it i estimated that a primary surface irrigation supply of 107,000 acre-fee each season would be required. In addition to the primary wate requirements for the nonabsorptive areas, it was assumed that th Madera unit, because of rights to acquire San Joaquin River wate initiated by the Madera Irrigation District, should be furnished with surface irrigation supply each season with a primary supply of no less than 31,000 acre-feet in a season of minimum yield.

This requirement for a primary irrigation supply totaling 138,00 acre-feet in each season was given first consideration in the operatio of Friant Reservoir. In order to insure the furnishing of this amoun of primary water, sufficient water would be held in reserve in the earl part of the season to provide the primary water supply throughout th season. The reservoir would be operated in a specific manner so tha the amount of water held in reserve at any particular time during th season would be sufficient to meet the requirements of primary suppl for the balance of the season. However, in seasons having a run-o above normal, the reservoir would be drawn down below the amount o storage reserve required for primary water in anticipation of subse quent heavy run-off from melting snow which would insure a primar supply for the balance of the season. Such operation would be base upon estimates made prior to March 1st by snow surveys, precipita tion and run-off data of the probable total seasonal run-off and of th balance of run-off to be expected in the remaining portion of the seaso

After providing for the primary supplies, the reservoir would be operated in general to deliver as much water as possible from the supplies available up to the maximum capacity of utilization under conditions of present development for both direct surface application and ground water storage. In the study of reservoir operation, the needs of the Madera unit were given first consideration after satisfying requirements for primary supply because of the assumed right initiated by the Madera Irrigation District to acquire San Joaquin River water. An attempt was made to furnish a surface irrigation supply of 150,000 acre-feet per season in accord with the irrigation demand shown in Table 123 with a minimum amount of not less than 31,000 acre-feet in a season of minimum yield. This basis of delivery of surface irrigation supplies to the Madera unit was generally adhered to, except during the month of August for a few seasons during the period studied when it was found necessary to deliver more of the water available to the units south of the San Joaquin River. In addition to the surface irrigation supply, water was delivered to the Madera unit, up to the maximum capacity of 1500 second-feet in the Madera Canal, for ground water storage and subsequent utilization by pumping, during periods when Friant Reservoir was spilling and during the months of March, April and May in seasons of above normal run-off when the reservoir stages were rising. The amount of water furnished the Madera unit on this basis was found to be adequate for present developments and it was assumed that this would be satisfactory to the Madera Irrigation District, provided the district would be protected in the matter of its assumed right to acquire about 350,000 acre-feet seasonally under conditions of ultimate development.

After providing for delivery of water to the Madera unit on the foregoing basis, the remainder of the supply available was delivered to the areas south of the San Joaquin River up to the maximum capacity of 3000 second-feet of the San Joaquin River-Kern County Canal during the months of March to October inclusive, and at a rate of 2300 second-feet in the remaining months.

Based upon the foregoing bases of operation of Friant Reservoir, the seasonal utilization of the impaired run-off of the San Joaquin River at Friant under conditions of immediate initial development which would have been effected during the 40-year period 1889–1929 is shown for each season in Table 153. There are set forth in this table the seasonal supplies provided for crop land rights, the amounts of in-season and out of season water diverted to the upper San Joaquin Valley through the Madera and San Joaquin River-Kern County canals, the evaporation loss from the reservoir, the unregulated waste past the reservoir and the net seasonal accretion or depletion in reservoir storage. The table also shows the averages of these items for the 40-, 20-, 12-, 8-, and 5-year periods to and including 1929. The data in this table of the seasonal amounts of water furnished for the crop lands and for delivery to the upper San Joaquin Valley are graphically depicted on Plate LXX, "Yield From Grass Land Rights and Surplus Waters of San Joaquin River at Friant Under Plan of Immediate Initial Development."

TABLE 153

SEASONAL UTILIZATION OF THE IMPAIRED RUN-OFF OF THE SAN JOAQUIN RIVER AT FRIANT RESERVOIR UNDER CONDITIONS OF IMMEDIATE INITIAL DEVELOPMENT, 1889-1929

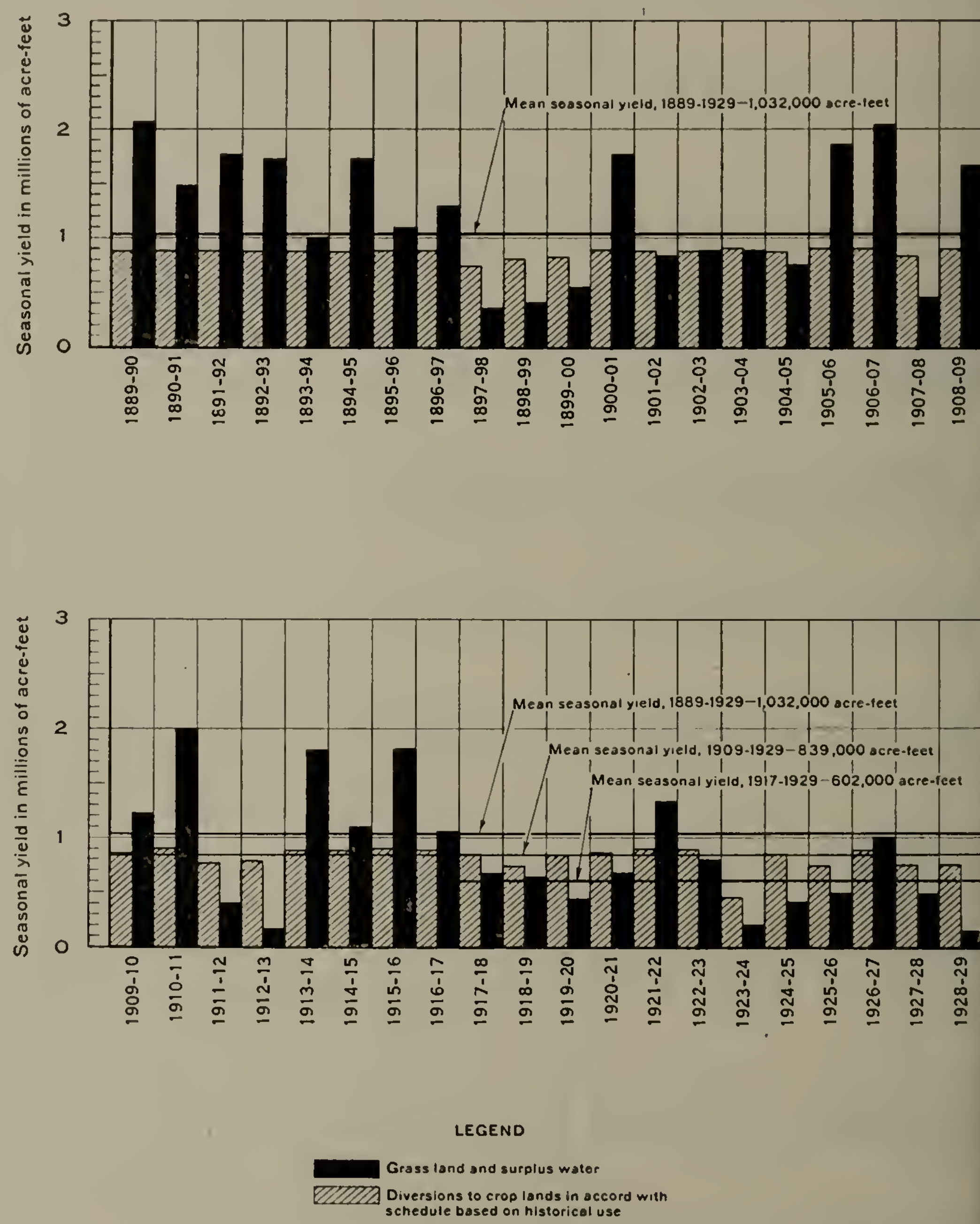
Quantities in Acre-feet

Season	Prior crop land rights	Diversions for upper San Joaquin Valley							Reservoir evaporation loss	Waste past reservoir	Net contribution to reservoir storage	Total impaired run-off[1]
		Madera Canal			San Joaquin River-Kern County Canal			Totals				
		In season	Out-of-season	Totals	In season	Out-of-season	Totals					
1889-90	895,700	150,000	331,200	481,200	849,000	747,500	1,596,500	2,077,700	15,100	1,442,100	0	4,430,600
1890-91	895,200	132,100	113,700	245,800	684,600	561,400	1,246,000	1,491,800	11,200	0	0	2,398,200
1891-92	895,700	141,400	151,400	292,800	793,500	687,000	1,480,500	1,773,300	13,700	235,600	0	2,918,300
1892-93	895,700	141,400	136,200	277,600	792,400	660,300	1,452,700	1,730,300	13,500	132,400	0	2,771,900
1893-94	888,800	132,100	0	132,100	560,400	296,200	856,600	988,700	10,900	0	0	1,888,400
1894-95	895,700	141,400	113,700	255,100	802,900	680,400	1,483,300	1,738,400	13,200	102,400	0	2,749,700
1895-96	893,600	126,100	10,000	136,100	654,000	316,900	970,900	1,107,000	12,500	0	0	2,013,100
1896-97	882,400	131,600	70,700	202,300	664,600	433,600	1,098,200	1,300,500	12,500	42,800	0	2,238,200
1897-98	739,900	62,500	0	62,500	202,300	77,400	279,700	342,200	10,900	0	0	1,093,000
1898-99	801,500	103,300	0	103,300	277,600	0	277,600	380,900	10,900	0	0	1,193,300
1899-90	806,900	96,000	0	96,000	337,900	91,700	429,600	525,600	10,900	0	0	1,343,400
1900-01	895,700	141,400	146,500	287,900	764,500	683,900	1,448,400	1,736,300	14,100	225,900	0	2,872,000
1901-02	862,900	116,200	0	116,200	555,800	146,000	701,800	818,000	11,000	0	0	1,691,900
1902-03	872,300	116,200	0	116,200	591,800	171,200	763,000	879,200	11,900	0	0	1,763,400
1903-04	891,000	132,100	0	132,100	587,700	166,000	753,700	885,800	12,300	0	0	1,789,100
1904-05	859,500	116,200	0	116,200	446,700	171,800	618,500	734,700	10,900	0	0	1,605,100
1905-06	895,700	150,000	267,500	417,500	818,600	623,900	1,442,500	1,860,000	14,500	1,041,700	+81,300	3,893,200
1906-07	895,700	150,000	296,400	446,400	860,000	715,400	1,575,400	2,021,800	14,100	74,400	−81,300	2,924,700
1907-08	836,800	62,500	0	62,500	275,700	126,500	402,200	464,700	10,900	0	0	1,312,400
1908-09	895,700	141,400	115,400	256,800	765,500	645,700	1,411,200	1,668,000	13,200	196,300	0	2,773,200
1909-10	861,600	116,200	6,700	122,900	459,300	633,400	1,092,700	1,215,600	10,700	0	0	2,087,900
1910-11	895,700	150,000	330,600	480,600	853,800	666,400	1,520,200	2,000,800	15,000	624,300	0	3,535,800
1911-12	757,700	90,300	0	90,300	287,500	23,300	310,800	401,100	10,900	0	0	1,169,700
1912-13	785,200	31,000	0	31,000	107,000	0	107,000	138,000	10,500	0	−4,800	928,900
1913-14	895,700	148,300	189,900	338,200	807,500	658,700	1,466,200	1,804,400	14,200	4,300	+4,800	2,723,400
1914-15	890,600	132,100	0	132,100	745,400	226,700	972,100	1,104,200	12,000	0	0	2,006,800
1915-16	895,700	141,400	259,100	400,500	771,600	649,200	1,420,800	1,821,300	13,700	28,900	0	2,759,600
1916-17	887,600	132,100	0	132,100	666,100	261,800	927,900	1,060,000	11,700	0	0	1,959,300
1917-18	864,000	116,200	0	116,200	464,500	90,000	554,500	670,700	11,200	0	0	1,545,900
1918-19	728,500	90,500	0	90,500	396,200	137,000	533,200	623,700	10,900	0	0	1,363,100

1919–20	843,600	104,900	0	104,900	288,900	52,300	341,200	446,100	10,900	0	0	1,300,600
1920–21	870,500	116,200	0	116,200	460,000	102,300	562,300	678,500	10,900	0	0	1,559,900
1921–22	892,100	132,100	113,700	245,800	753,200	338,300	1,091,500	1,337,300	12,100	38,000	0	2,279,500
1922–23	886,900	132,100	0	132,100	453,600	200,000	653,600	785,700	10,900	0	0	1,683,500
1923–24	460,800	32,700	0	32,700	147,100	2,500	149,600	182,300	10,900	0	0	654,000
1924–25	861,100	104,900	0	104,900	275,900	20,700	296,600	401,500	10,900	0	0	1,273,500
1925–26	736,900	90,500	0	90,500	335,100	58,600	393,700	484,200	10,900	0	0	1,232,000
1926–27	878,800	130,400	0	130,400	598,300	266,600	864,900	995,300	11,600	0	0	1,885,700
1927–28	739,400	90,500	0	90,500	314,100	74,500	388,600	479,100	10,900	0	0	1,229,400
1928–29	768,300	32,700	0	32,700	108,000	0	108,000	140,700	10,500	0	—3,100	916,400
40-year average, 1889–1929	845,000	115,000	66,300	181,300	539,500	311,600	851,100	1,032,400	12,000	104,700	—100	1,994,000
20-year average, 1909–1929	820,000	105,800	45,000	150,800	464,700	223,100	687,800	838,600	11,600	34,800	—200	1,704,800
12-year average, 1917–1929	794,200	97,800	9,500	107,300	382,900	111,900	494,800	602,100	11,100	3,200	—300	1,410,300
8-year average, 1921–1929	778,000	93,300	14,200	107,500	373,200	120,100	493,300	600,800	11,100	4,800	—400	1,394,300
5-year average, 1924–1929	796,900	89,800	0	89,800	326,300	84,100	410,400	500,200	11,000	0	—600	1,307,500

[1] Existing upstream power storage assumed to be operated without interference with crop land schedule.

PLATE LXX



YIELD FROM

GRASS LAND RIGHTS AND SURPLUS WATERS

OF

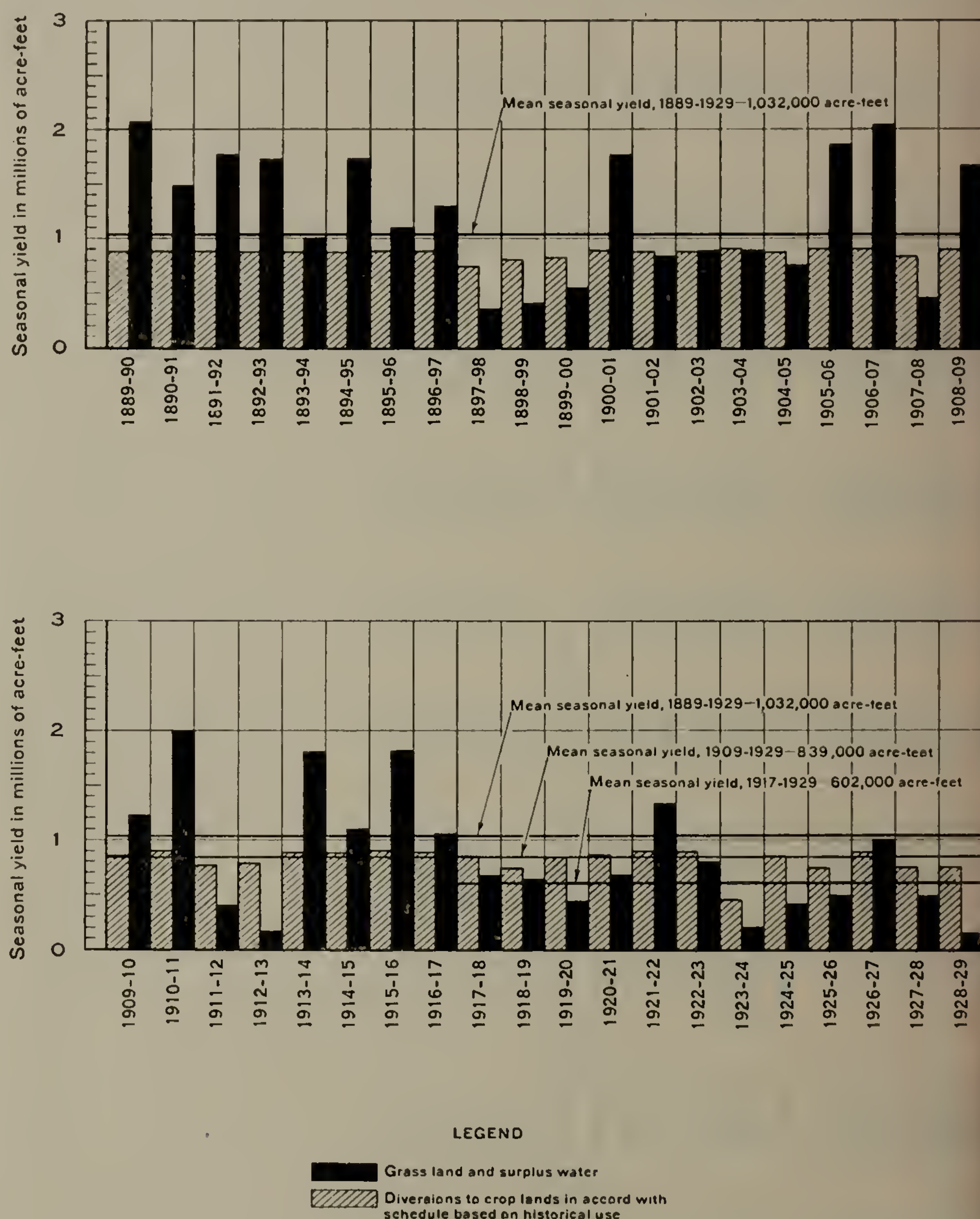
SAN JOAQUIN RIVER AT FRIANT

UNDER

PLAN OF IMMEDIATE INITIAL DEVELOPMENT

Season	September		The Season		
	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Totals
1889-90	10,800	114,900	481,200	1,596,500	2,077,700
1890-91	2,200	15,700	245,800	1,246,000	1,491,800
1891-92	2,200	19,500	292,800	1,480,500	1,773,300
1892-93	2,200	18,400	277,600	1,452,700	1,730,300
1893-94	2,200	12,000	132,100	856,600	988,700
1894-95	2,200	32,600	255,100	1,483,300	1,738,400
1895-96	2,200	15,100	136,100	970,900	1,107,000
1896-97	2,200	10,800	202,300	1,098,200	1,300,500
1897-98	2,200	10,800	62,500	279,700	342,200
1898-99	2,200	10,800	103,300	277,600	380,900
1899-00	2,200	10,800	96,000	429,600	525,600
1900-01	2,200	18,500	287,900	1,448,400	1,736,300
1901-02	2,200	10,800	116,200	701,800	818,000
1902-03	2,200	10,800	116,200	763,000	879,200
1903-04	2,200	20,600	132,100	753,700	885,800
1904-05	2,200	10,800	116,200	618,500	734,700
1905-06	10,800	178,500	417,500	1,442,500	1,860,000
1906-07	10,800	91,200	446,400	1,575,400	2,021,800
1907-08	2,200	10,800	62,500	402,200	464,700
1908-09	2,200	36,600	256,800	1,411,200	1,668,000
1909-10	2,200	23,700	122,900	1,092,700	1,215,600
1910-11	10,800	86,800	480,600	1,520,200	2,000,800
1911-12	2,200	10,800	90,300	310,800	401,100
1912-13	2,200	10,800	31,000	107,000	138,000
1913-14	10,800	94,800	338,200	1,466,200	1,804,400
1914-15	2,200	16,000	132,100	972,100	1,104,200
1915-16	2,200	13,100	400,500	1,420,800	1,821,300
1916-17	2,200	10,800	132,100	927,900	1,060,000
1917-18	2,200	18,900	116,200	554,500	670,700
1918-19	2,200	10,800	90,500	533,200	623,700
1919-20	2,200	10,800	104,900	341,200	446,100
1920-21	2,200	10,800	116,200	562,300	678,500
1921-22	2,200	10,800	245,800	1,091,500	1,337,300
1922-23	2,200	12,400	132,100	653,600	785,700
1923-24	2,200	10,800	32,700	149,600	182,300
1924-25	2,200	10,800	104,900	296,600	401,500
1925-26	2,200	10,800	90,500	393,700	484,200
1926-27	2,200	10,800	130,400	864,900	995,300
1927-28	2,200	10,800	90,500	388,600	479.100
1928-29	2,200	10,800	32,700	108,000	140,700
Averages 1889-1929	3,300	26,700	181,300	851,100	1,032,400

PLATE LXX



YIELD FROM

GRASS LAND RIGHTS AND SURPLUS WATERS

OF

SAN JOAQUIN RIVER AT FRIANT

UNDER

PLAN OF IMMEDIATE INITIAL DEVELOPMENT

TABLE 154

MONTHLY DIVERSIONS FROM SAN JOAQUIN RIVER AT FRIANT RESERVOIR TO UPPER SAN JOAQUIN VALLEY UNDER CONDITIONS OF IMMEDIATE INITIAL DEVELOPMENT, 1889-1929

Quantities in Acre-feet

Season	October		November		December		January		February		March	
	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal
1889-90	2,100	32,000	0	36,200	0	49,700	0	141,400	1,600	127,700	92,200	184,400
1890-91	2,100	46,500	0	29,700	0	28,400	0	111,900	1,600	119,200	10,500	178,900
1891-92	2,100	44,300	0	35,300	0	33,800	0	121,400	1,600	132,300	10,500	184,400
1892-93	2,100	43,400	0	33,400	0	31,500	0	122,800	1,600	127,700	10,500	184,400
1893-94	2,100	36,200	0	23,600	0	18,900	0	84,400	1,600	95,500	10,500	112,300
1894-95	2,100	39,300	0	12,200	0	47,400	0	141,400	1,600	127,700	10,500	179,300
1895-96	2,100	37,000	0	19,300	0	6,400	0	115,400	1,600	78,500	10,500	127,800
1896-97	2,100	27,900	0	29,400	0	17,500	0	41,900	1,600	118,500	10,500	133,700
1897-98	2,100	30,200	0	36,200	0	28,600	0	34,900	1,600	37,900	10,500	18,800
1898-99	1,500	5,500	0	1,100	0	1,100	0	2,200	300	3,300	10,500	35,800
1899-00	2,100	6,000	0	7,500	0	6,600	0	108,900	1,600	13,300	10,500	59,100
1900-01	2,100	15,000	0	64,300	0	19,000	0	141,400	7,100	127,700	37,800	184,400
1901-02	2,100	44,700	0	30,400	0	26,400	0	47,400	1,600	42,600	10,500	71,700
1902-03	2,100	27,800	0	18,900	0	3,100	0	52,800	1,600	46,200	10,500	57,200
1903-04	2,100	26,200	0	8,300	0	1,100	0	2,200	1,600	8,300	10,500	109,300
1904-05	2,100	89,100	0	27,800	0	5,700	0	42,400	1,600	63,200	10,500	104,100
1905-06	2,100	16,600	0	1,100	0	1,100	0	92,600	1,600	58,000	92,200	184,400
1906-07	2,100	128,400	0	18,100	0	23,600	0	101,500	1,600	118,000	67,200	184,400
1907-08	2,100	47,800	0	19,700	0	17,600	0	62,300	1,600	57,200	10,500	85,300
1908-09	2,100	12,900	0	1,100	0	1,100	0	141,400	1,600	127,700	10,500	180,200
1909-10	2,100	36,800	0	34,800	0	134,100	0	141,400	1,600	113,100	10,500	182,500
1910-11	2,100	36,800	0	18,000	0	14,900	0	141,400	1,600	127,700	92,200	184,400
1911-12	2,100	37,700	0	16,100	0	4,600	0	33,000	1,600	22,300	10,500	25,900
1912-13	400	5,500	0	1,100	0	1,100	0	2,200	300	3,300	2,200	7,500
1913-14	400	5,500	0	1,100	0	1,100	0	141,400	1,600	127,700	10,500	184,400
1914-15	2,100	41,100	0	14,100	0	5,300	0	45,600	1,600	85,400	10,500	92,000
1915-16	2,100	27,600	0	8,500	0	11,200	0	141,400	1,600	132,300	92,200	184,400
1916-17	2,100	53,400	0	20,700	0	17,200	0	48,700	1,600	123,600	10,500	73,900
1917-18	2,100	28,200	0	8,700	0	1,100	0	2,200	1,600	22,200	10,500	109,200
1918-19	2,100	78,500	0	11,500	0	5,000	0	30,200	1,600	47,400	10,500	48,100
1919-20	400	5,500	0	1,100	0	1,100	0	2,200	300	3,300	2,200	7,500
1920-21	2,100	13,100	0	10,400	0	1,100	0	21,800	1,600	57,400	10,500	116,800
1921-22	2,100	26,200	0	1,100	0	1,300	0	41,400	1,600	73,900	10,500	85,700
1922-23	2,100	26,200	0	18,500	0	56,600	0	63,500	1,600	54,200	10,500	63,600
1923-24	2,100	38,100	0	11,100	0	1,100	0	2,200	300	3,300	2,200	7,500
1924-25	400	5,500	0	1,100	0	1,100	0	2,200	300	3,300	2,200	7,500
1925-26	2,100	28,500	0	1,100	0	1,100	0	2,200	1,600	17,800	10,500	45,500
1926-27	400	5,500	0	3,400	0	1,100	0	19,000	1,600	127,600	10,500	98,600
1927-28	2,100	32,000	0	43,500	0	16,200	0	29,800	1,600	33,700	10,500	71,700
1928-29	2,100	6,500	0	1,100	0	1,100	0	2,200	300	3,300	2,200	7,500
Averages 1889-1929	1,900	32,400	0	17,000	0	16,100	0	65,600	1,500	70,300	19,700	104,100

Season	April		May		June		July		August		September		The Season		
	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Totals
1889-90	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	11,700	184,400	10,800	114,900	481,200	1,596,500	2,077,700
1890-91	25,500	178,500	92,200	184,400	89,200	178,500	20,100	159,000	2,400	15,300	2,200	15,700	245,800	1,246,000	1,491,800
1891-92	63,200	178,500	92,200	184,400	89,200	178,500	20,100	184,400	11,700	183,700	2,200	19,500	292,800	1,480,500	1,773,300
1892-93	48,000	178,500	92,200	184,400	89,200	178,500	20,100	184,400	11,700	165,300	2,200	18,400	277,600	1,452,700	1,730,300
1893-94	25,500	84,000	35,300	164,900	32,400	175,000	20,100	34,500	2,400	15,300	2,200	12,000	132,100	856,600	988,700
1894-95	25,500	178,500	92,200	184,400	89,200	178,500	20,100	184,400	11,700	177,600	2,200	32,600	255,100	1,483,300	1,738,400
1895-96	19,500	16,800	35,300	77,100	42,400	178,500	20,100	184,400	2,400	114,600	2,200	15,100	136,100	970,900	1,107,000
1896-97	39,300	178,500	92,200	184,400	32,400	178,500	19,600	161,800	2,400	15,300	2,200	10,800	202,300	1,098,200	1,300,500
1897-98	25,500	18,300	7,300	14,600	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	62,500	279,700	342,200
1898-99	25,500	79,900	24,300	21,900	32,400	83,500	4,200	17,200	2,400	15,300	2,200	10,800	103,300	277,600	380,900
1899-00	5,300	11,500	35,300	89,000	32,400	84,400	4,200	17,200	2,400	15,300	2,200	10,800	96,000	429,600	525,600
1900-01	25,500	178,500	92,200	184,400	89,200	178,500	20,100	184,400	11,700	152,300	2,200	18,500	287,900	1,448,400	1,736,300
1901-02	25,500	83,000	35,300	125,700	32,400	178,500	4,200	25,300	2,400	15,300	2,200	10,800	116,200	701,800	818,000
1902-03	25,500	39,500	35,300	184,400	32,400	178,500	4,200	128,500	2,400	15,300	2,200	10,800	116,200	763,000	879,200
1903-04	25,500	49,900	35,300	184,400	32,400	178,500	20,100	149,600	2,400	15,300	2,200	20,600	132,100	753,700	885,800
1904-05	25,500	25,000	35,300	99,000	32,400	118,900	4,200	17,200	2,400	15,300	2,200	10,800	116,200	618,500	734,700
1905-06	25,500	178,500	92,200	184,400	89,200	178,500	92,200	184,400	11,700	184,400	10,800	178,500	417,500	1,442,500	1,860,000
1906-07	79,400	178,500	92,200	184,400	89,200	178,500	92,200	184,400	11,700	184,400	10,800	91,200	446,400	1,575,400	2,021,800
1907-08	25,500	37,500	7,300	14,600	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	62,500	402,200	464,700
1908-09	27,200	178,500	92,200	184,400	89,200	178,500	20,100	184,400	11,700	184,400	2,200	36,600	256,800	1,411,200	1,668,000
1909-10	25,500	178,500	42,000	184,400	32,400	30,900	4,200	17,200	2,400	15,300	2,200	23,700	122,900	1,092,700	1,215,600
1910-11	89,200	178,500	91,600	184,400	89,200	178,500	92,200	184,400	11,700	184,400	10,800	86,800	480,600	1,520,200	2,000,800
1911-12	5,300	11,500	29,600	21,900	32,400	94,500	4,200	17,200	2,400	15,300	2,200	10,800	90,300	310,800	401,100
1912-13	5,300	11,500	7,300	14,600	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	31,000	107,000	138,000
1913-14	58,500	178,500	92,200	184,400	89,200	178,500	63,300	184,400	11,700	184,400	10,800	94,800	338,200	1,466,200	1,804,400
1914-15	25,500	101,000	35,300	127,700	32,400	178,500	20,100	184,400	2,400	81,000	2,200	16,000	132,100	972,100	1,104,200
1915-16	89,200	178,500	92,200	184,400	89,200	178,500	20,100	184,400	11,700	176,500	2,200	13,100	400,500	1,420,800	1,821,300
1916-17	25,500	70,800	35,300	113,700	32,400	178,500	20,100	184,400	2,400	32,200	2,200	10,800	132,100	927,900	1,060,000
1917-18	25,500	34,400	35,300	78,400	32,400	178,500	4,200	57,400	2,400	15,300	2,200	18,900	116,200	554,500	670,700
1918-19	25,500	62,300	35,300	184,400	6,700	22,500	4,200	17,200	2,400	15,300	2,200	10,800	90,500	533,200	623,700
1919-20	25,500	21,800	35,300	172,700	32,400	82,700	4,200	17,200	2,400	15,300	2,200	10,800	104,900	341,200	446,100
1920-21	25,500	43,400	35,300	108,000	32,400	145,300	4,200	18,900	2,400	15,300	2,200	10,800	116,200	562,300	678,500
1921-22	25,500	141,800	92,200	184,400	89,200	178,500	20,100	184,400	2,400	162,000	2,200	10,800	245,800	1,091,500	1,337,300
1922-23	25,500	56,800	35,300	184,400	32,400	68,900	20,100	33,200	2,400	15,300	2,200	12,400	132,100	653,600	785,700
1923-24	5,300	11,500	7,300	14,000	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	32,700	149,600	182,300
1924-25	25,500	38,000	35,300	141,100	32,400	53,500	4,200	17,200	2,400	15,300	2,200	10,800	104,900	296,600	401,500
1925-26	25,500	153,200	35,300	84,100	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	90,500	393,700	484,200
1926-27	25,500	114,300	35,300	184,400	32,400	178,500	20,100	106,400	2,400	15,300	2,200	10,800	130,400	864,900	995,300
1927-28	25,500	27,200	35,300	74,300	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	90,500	388,600	479,100
1928-29	5,300	11,500	7,300	14,000	6,700	16,900	4,200	17,200	2,400	15,300	2,200	10,800	32,700	108,000	140,700
Averages 1889-1929	31,700	96,400	51,400	131,500	46,000	125,100	20,800	97,500	5,000	68,400	3,300	26,700	181,300	851,100	1,032,400

80997—Bet. pp. 404 and 405

Table 154 shows the monthly diversions to the upper San Joaquin Valley through the Madera and San Joaquin River-Kern County canals for each season during the 40-year period. The diversions through the latter canal are graphically shown on Plate LXXI, "Yield From Friant Reservoir for San Joaquin River-Kern County Canal Under Plan of Immediate Initial Development, 1889–1929."

Under the proposed plan of operation, Friant Reservoir would have furnished a primary surface irrigation supply of 138,000 acre-feet each season with 31,000 acre-feet delivered to the Madera unit and 107,000 acre-feet to the non-absorptive areas served by the San Joaquin River-Kern County Canal south of the San Joaquin River. The average seasonal supply for the 40-year period 1889–1929 would have been 1,032,000 acre-feet of which the Madera area would have received 181,000 acre-feet. The average for the 20-year period 1909-1929 would have been 839,000 acre-feet of which the Madera area would have received 151,000 acre-feet. The averages for the 12-, 8-, and 5-year periods would have amounted respectively to 602,000, 601,000 and 500,000 acre-feet of which the Madera area would have received 107,000, 108,000 and 90,000 acre-feet, respectively.

Comparing the average seasonal amounts of water supply that would have been made available for the upper San Joaquin Valley during the 8-year period 1921–1929 with the average seasonal deficiencies shown in Table 142, it is evident that the amount of supplemental water supply would be more than sufficient to meet these deficiencies in all areas requiring immediate relief in the upper San Joaquin Valley. The average seasonal supplemental supply for the Madera area during the 8-year period 1921–1929 would have been 108,000 acre-feet as compared to an estimated average seasonal deficiency of 61,000 acre-feet. For the area south of the San Joaquin River, the average seasonal supplemental supply would have been 493,000 acre-feet as compared to an estimated average seasonal deficiency of 326,000 acre-feet. The amount of supplemental supply in excess of deficiencies could have been utilized to replenish the underground reservoirs and also to furnish a supply to the areas north of lower Kings River adjacent to the valley trough, which are troubled with mineralized ground water.

The allocation of the supplemental water supplies furnished from Friant Reservoir to the areas requiring immediate relief on the east side of the upper San Joaquin Valley south of the San Joaquin River has been based not only upon the average deficiencies in supply and estimated needs for immediate relief but also upon the needs for ground water replenishment in the absorptive areas of deficient water supply. The need and desirability of reducing present pumping lifts by ground water replenishment and raising of ground water levels in these absorptive areas varies with the depth of depletion. Therefore, the total lowering of the ground water levels, together with the volume of depletion during the period of record 1921–1929, was used as a factor in estimating the relative requirements for these ground water units under conditions of initial development.

The combined requirements for meeting the present deficiencies in supply and providing for the desirable amount of ground water replenishment are estimated for the Kaweah, Tule-Deer Creek, Earlimart-Delano and McFarland-Shafter ground water units at 103,000, 80,000, 104,000 and 95,000 acre-feet, respectively. These relative quantities would be used for proportioning to ground water units the supplemental water supplies which do not exceed the average for the period 1921–1929. A modification in seasons of large run-off would be required because of low rates of absorption in certain areas and the value of excess supply for reducing pumping lifts of local and imported water in highly absorptive areas. Furthermore, actual irrigation requirements would become the prime factor in determining redistribution when ground water in these areas would have been replenished.

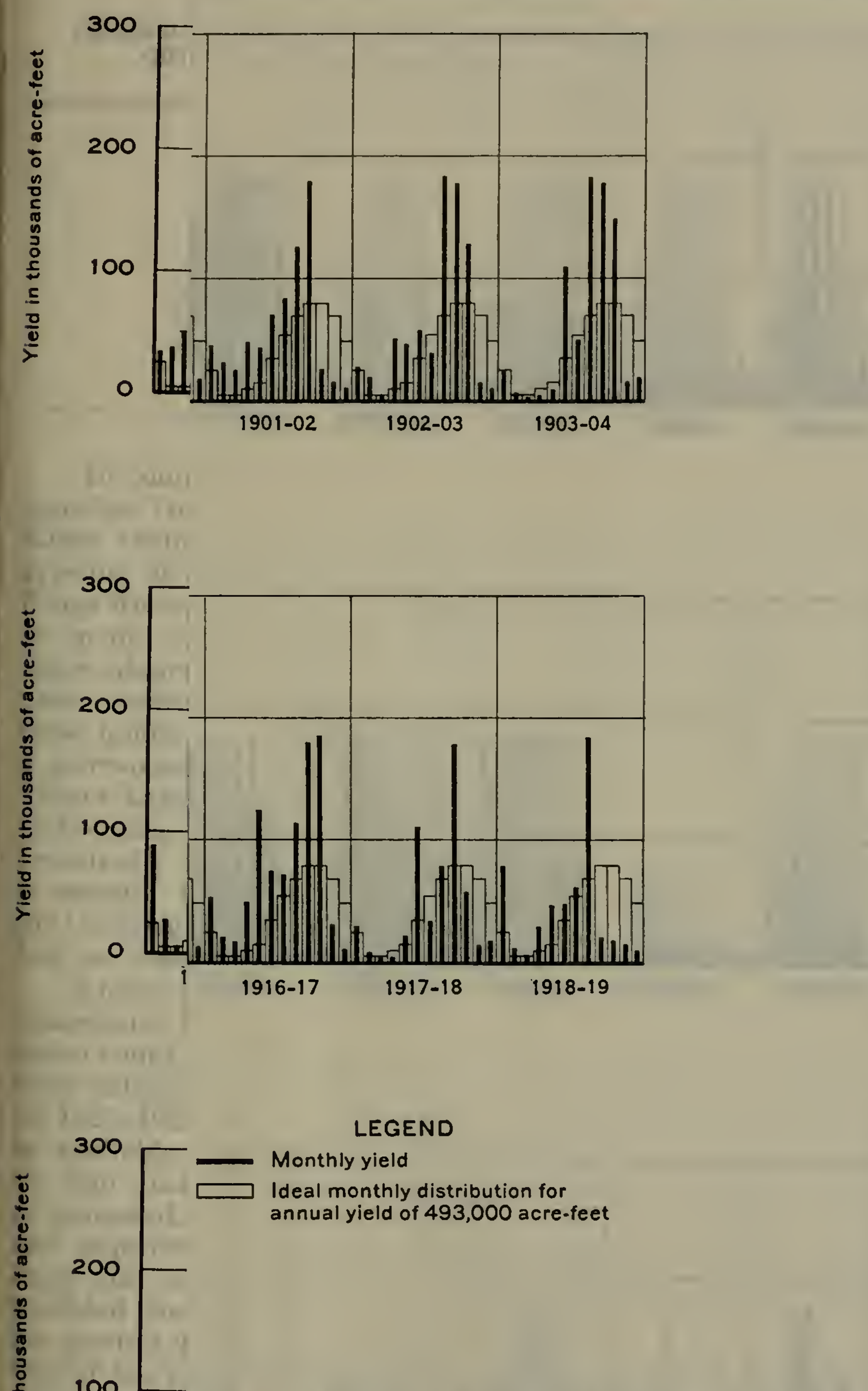
The desirable supplemental water supply for the area north of the lower Kings River is not known, but it is estimated that a seasonal supply of 35,000 acre-feet on the average would be adequate. The desirable amounts of primary surface irrigation supplies for the principal non-absorptive areas are estimated at 35,000 acre-feet for the Alta-Foothill unit of 16,000 acres, 6000 acre-feet for the Magunden-Edison unit of 2600 acres and 35,000 acre-feet for the Lindsay unit of 22,000 acres.

On the foregoing bases of allocation and consideration of the methods of irrigation practiced in the several areas, it is concluded that an equitable distribution of the average seasonal amount of supplemental water supply which would have been furnished from Friant Reservoir during the period 1921–1929 would be in accordance with the amounts set forth in Tables 155 and 156. Table 155 gives the distribution by units and Table 156 by counties. The amount of water allocated to the Tule-Deer Creek unit includes a supplemental supply for about 5000 acres of developed land lying east of this unit.

TABLE 155

DISTRIBUTION BY GROUND WATER UNITS OF WATER SUPPLY FOR AN AVERAGE SEASON OBTAINABLE FROM SURPLUS AND "GRASS LAND" RIGHTS OF SAN JOAQUIN RIVER, 1921-1929

Unit	Average seasonal water supply available at Friant reservoir, in acre-feet
Madera	108,000
Alta-Foothill (comprising Foothill Irrigation District and 5,000 acres in Alta Irrigation District)	35,000
Kaweah	103,000
Lindsay	35,000
Tule-Deer Creek	80,000
Earlimart-Delano	104,000
McFarland-Shafter	95,000
Magunden-Edison (portion of Edison-Arvin)	6,000
Lower Kings River area	35,000
Total	601,000



FROM FRIANT RESERVOIR

FOR

IN RIVER--KERN COUNTY CANAL

UNDER

OF IMMEDIATE INITIAL DEVELOPMENT

)997

104,000 and 95,000 acre-feet, respectively. These relative quantities would be used for proportioning to ground water units the supplemental water supplies which do not exceed the average for the period 1921–1929. A modification in seasons of large run-off would be required because of low rates of absorption in certain areas and the value of excess supply for reducing pumping lifts of local and imported water in highly absorptive areas. Furthermore, actual irrigation requirements would become the prime factor in determining redistribution when ground water in these areas would have been replenished.

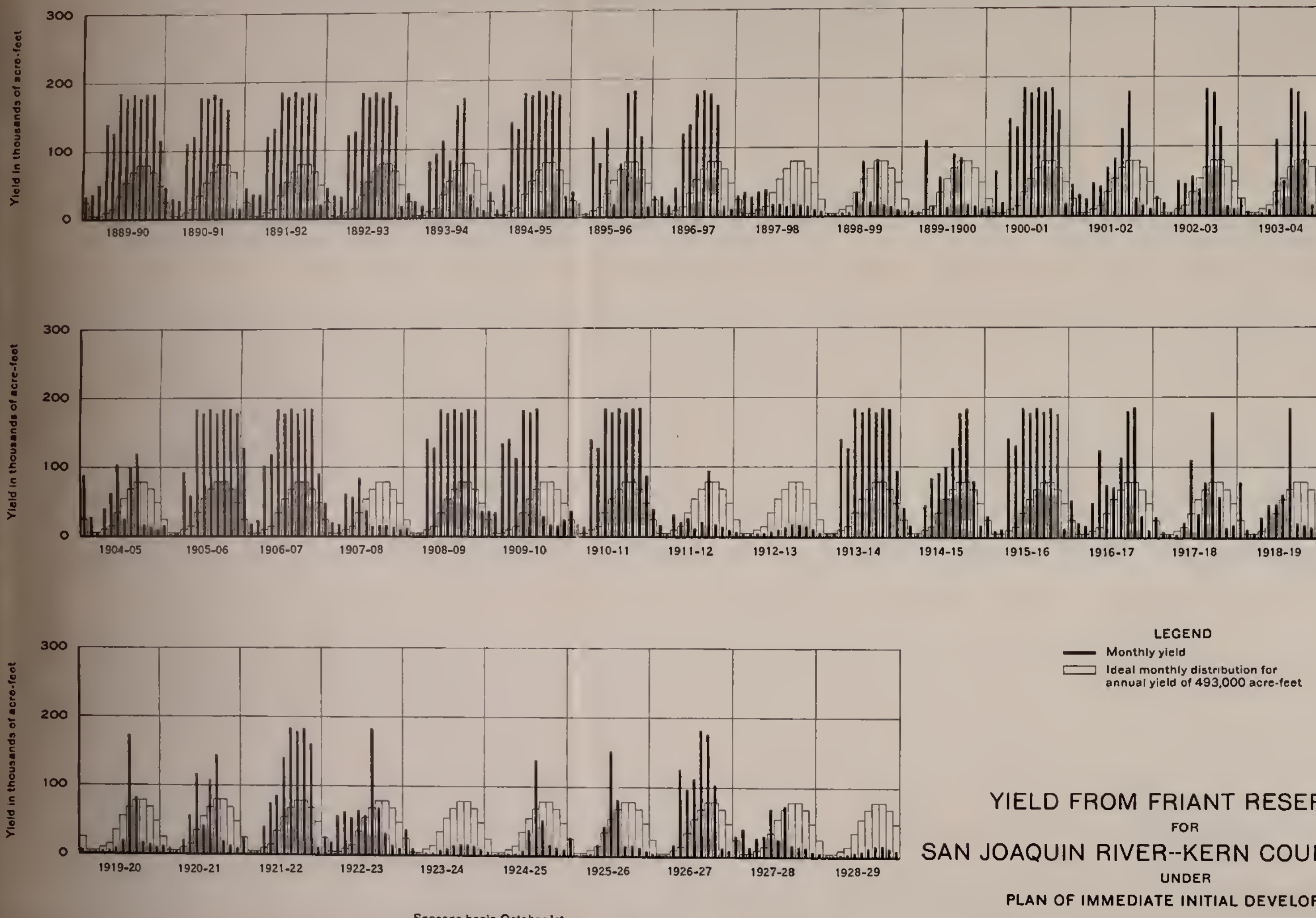
The desirable supplemental water supply for the area north of the lower Kings River is not known, but it is estimated that a seasonal supply of 35,000 acre-feet on the average would be adequate. The desirable amounts of primary surface irrigation supplies for the principal non-absorptive areas are estimated at 35,000 acre-feet for the Alta-Foothill unit of 16,000 acres, 6000 acre-feet for the Magunden-Edison unit of 2600 acres and 35,000 acre-feet for the Lindsay unit of 22,000 acres.

On the foregoing bases of allocation and consideration of the methods of irrigation practiced in the several areas, it is concluded that an equitable distribution of the average seasonal amount of supplemental water supply which would have been furnished from Friant Reservoir during the period 1921–1929 would be in accordance with the amounts set forth in Tables 155 and 156. Table 155 gives the distribution by units and Table 156 by counties. The amount of water allocated to the Tule-Deer Creek unit includes a supplemental supply fo[r] about 5000 acres of developed land lying east of this unit.

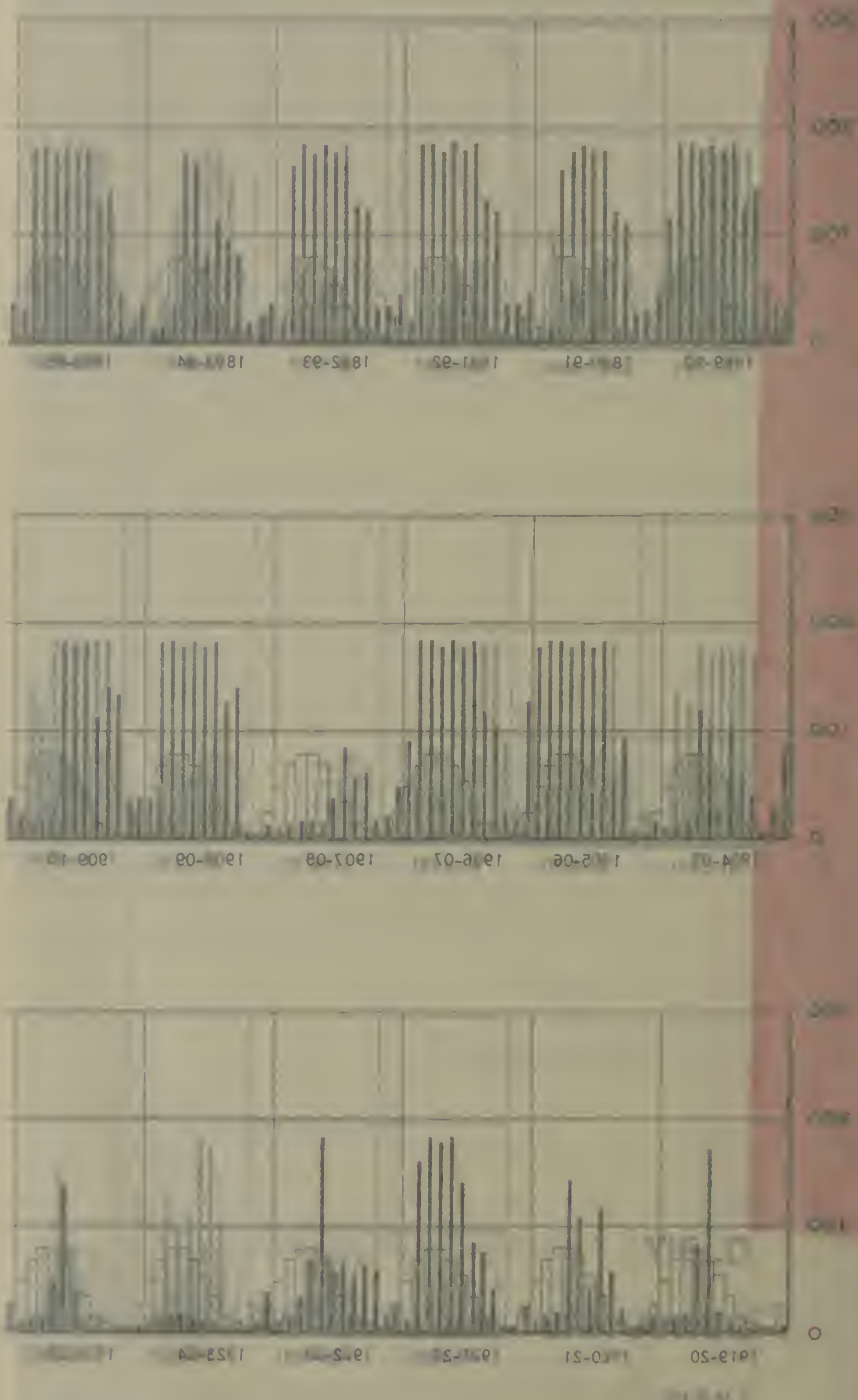
TABLE 155

DISTRIBUTION BY GROUND WATER UNITS OF WATER SUPPLY FOR AN AVERAG[E] SEASON OBTAINABLE FROM SURPLUS AND "GRASS LAND" RIGHTS OF SAN JOAQUIN RIVER, 1921-1929

Unit	Average seasonal water supply available at Friant reservoir, in acre-feet
Madera	108,000
Alta-Foothill (comprising Foothill Irrigation District and 5,000 acres in Alta Irrigation District)	35,000
Kaweah	103,000
Lindsay	35,000
Tule-Deer Creek	80,000
Earlimart-Delano	104,000
McFarland-Shafter	95,000
Magunden-Edison (portion of Edison-Arvin)	6,000
Lower Kings River area	35,000
Total	601,000



YIELD FROM FRIANT RESERVOIR
FOR
SAN JOAQUIN RIVER--KERN COUNTY CANAL
UNDER
PLAN OF IMMEDIATE INITIAL DEVELOPMENT



1889-90
1890-91
1891-92
1892-93
1893-94
1905-06
1906-07
1907-08
1908-09
1919-20
1920-21
1923-24
Seasons begin October 1st

TABLE 156

DISTRIBUTION BY COUNTIES OF WATER SUPPLY FOR AN AVERAGE SEASON OBTAINABLE FROM SURPLUS AND "GRASS LAND" RIGHTS OF SAN JOAQUIN RIVER, 1921-1929

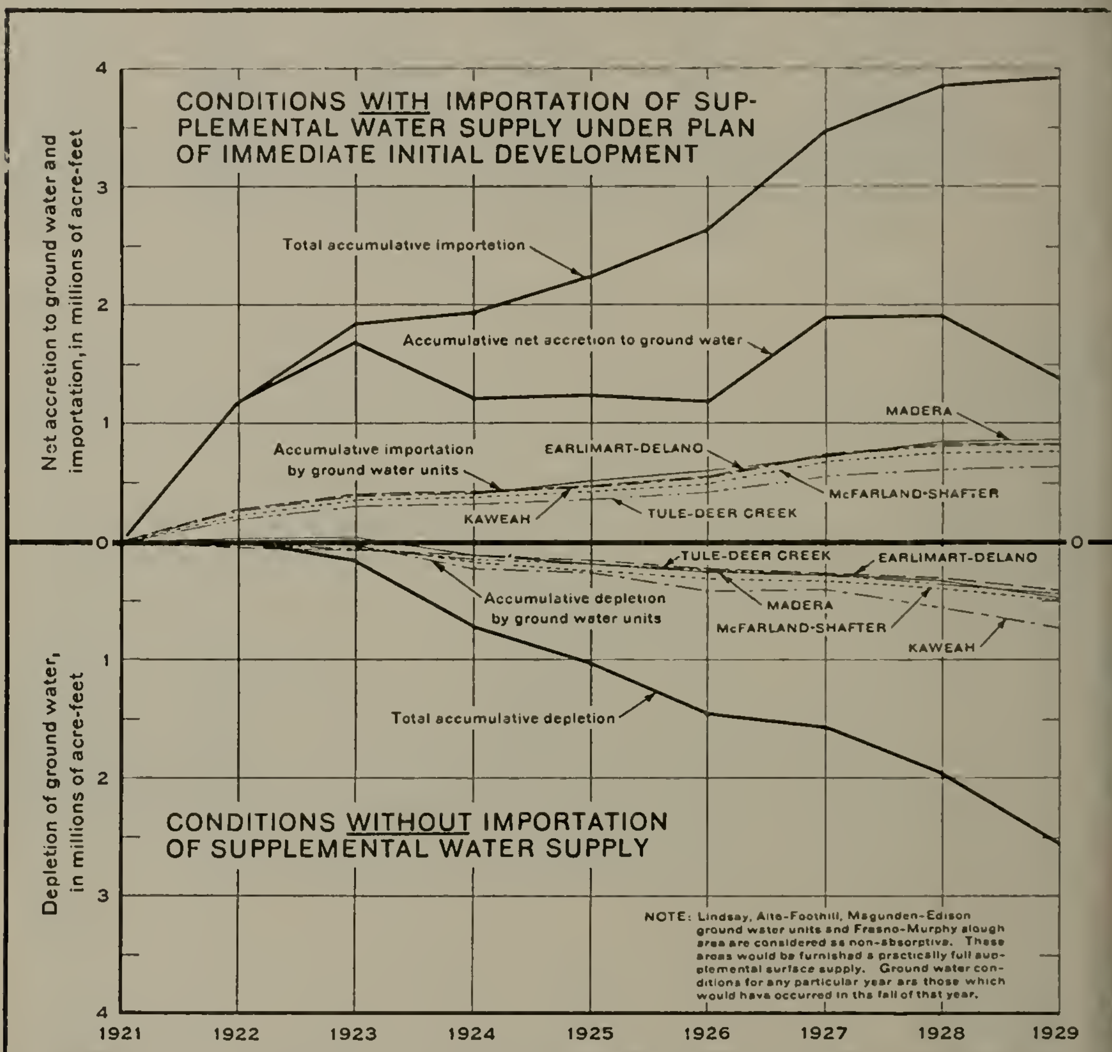
County	Average seasonal water supply available at Friant reservoir, in acre-feet
Madera	108,000
Fresno	50,000
Tulare	318,000
Kern	125,000
Total	601,000

In connection with the foregoing allocation of supplemental water supplies from the San Joaquin River, it is assumed that lands in Kings County lying in and east of Tulare Lake now used chiefly for growing of annual crops could be furnished a supply either from the Kings River, if properly regulated, or by pumping supplies, which could be made available under immediate initial development, from the lower absorptive areas of the Kaweah and Tule deltas. If it should prove desirable and necessary to furnish a direct surface supply to these lands, water would be available for that purpose, however, with a corresponding reduction in supply to some of the other areas. In Tulare Lake there are about 50,000 acres of land used for grain and in the area to the east of the lake there are about 20,000 acres used principally for growing of cotton. These acreages vary from season to season. If allowed a full surface supply from the imported water for the irrigation of these crops, it is estimated that about 90,000 acre-feet per season would be adequate.

Under the proposed plan of operation of Friant Reservoir for immediate initial development, the supplemental water supplies which could have been furnished by the regulation of surplus and grass land waters in the San Joaquin River, based upon the period of run-off 1921–1929, would have been fully adequate to meet the deficiencies in available local supplies and maintain present developed areas in the San Joaquin Valley, with the allocation of supplemental supplies as proposed. Not only would the deficiencies between local supply and requirements during the period 1921–1929 have been met but there also would have been water in excess of net use requirements provided for ground water replenishment. The resulting effect on the ground water reservoirs in the absorptive areas, under the operation of the plan, is illustrated on Plate LXXII, "Ground Water Conditions in Absorptive Areas in Upper San Joaquin Valley." On this plate there is shown, for each unit and for the entire area, the accumulative depletion under conditions without importation of a supplemental supply, and the accumulative importations of supplemental water; and also, for the entire area, the accumulative net accretion to ground water with the importations of supplemental water as proposed. As a result of the proposed plan of operation during the 8-year period 1921–1929, there would have been 1,361,000 acre-feet more water available in the underground reservoirs at the end of the period than at the beginning.

It has been shown that, under the plan of immediate initial development, the average seasonal supplemental supply during the eight-year period would have been 601,000 acre-feet. The importation of

PLATE LXXII



GROUND WATER CONDITIONS
IN
ABSORPTIVE AREAS IN UPPER SAN JOAQUIN VALLEY
WITH AND WITHOUT
SUPPLEMENTAL IMPORTATION UNDER PLAN OF IMMEDIATE INITIAL DEVELOPMENT
1921-1929

this supply into the areas of permanent deficiency not only would have more than doubled the utilizable water supply of these areas but also would have improved the characteristics of occurrence of the present deficient supplies. A substantial part of the seasonal inflow into these areas occurs now in months outside of the irrigation season. During the eight-year period 1921–1929, 41 per cent on the average so occurred, while 59 per cent occurred within the irrigation season. For the imported supplemental supply, the corresponding figures would have been 22 and 78 per cent and with the combination of the local and imported supplies, 32 and 68 per cent, respectively. Therefore, it is seen that with this plan not only would the present supplies have been more than doubled, but the characteristics of occurrence of the supply as related to demand would have been much improved. Table 157 sets forth these relative average values, for each of the areas receiving a supplemental water supply, for the eight-year period 1921–1929 and the twelve-year period 1917–1929 as well as corresponding values for typical seasons within the period.

The imported supplemental supplies provide only for the areas of permanent deficiency in the upper San Joaquin Valley. The data previously presented show that certain other areas, particularly the Fresno-Consolidated and Alta units, have had deficiencies in surface water supply in some seasons during dry periods such as that since 1921. However, experience demonstrates that such deficiencies are temporary and that, even though the water table is lowered by pumping water from underground in amounts exceeding the replenishment in dry seasons, ground water levels recover with seasons of more normal run-off before serious depletion occurs. For both areas of permanent and temporary deficiency in water supply in the upper San Joaquin Valley, it is assumed that ground water storage and pumping would be utilized to the fullest practicable extent. If substantial drafts were not made on ground water reservoirs in seasons of deficient surface supply, little or no space would be made available for the storage underground of surface run-off in excess of irrigation requirments in more normal seasons and substantial amounts of the local supply now conserved and utilized by underground storage and pumping would be wasted out of the basin.

Studies were made to ascertain what the conditions would be in the Fresno-Consolidated and Alta units, if they were furnished supplemental surface supplies during a dry period such as that since 1921. These studies showed that a seasonal importation each year of any large amounts of supplemental water would result in the maintenance of high ground water levels and the water-logging of large areas in the lower portions of the units. Actual experience in past years has demonstrated that large areas in both of these units have been water-logged even under the utilization of local supplies. The lowering of ground water levels which has taken place in more recent dry years has improved conditions and has permitted some of the previously water-logged lands to be brought back into production. It appears that an importation every year of regulated supplemental supplies would not be desirable for these areas taken as a whole, but that small amounts of supplemental water in seasons of deficient local surface supplies could be used to advantage in certain parts of these units and would result in a reduction in cost of ground water pumping.

The supplemental water supply available under the immediate initial development, based upon the run-off during the period 1917–1929, is sufficient in amount to care for the areas of permanent deficiency, only. If it should prove desirable or economical to furnish a certain amount of imported supplemental water to areas of temporary deficiency in dry seasons, the construction of the plan of complete initial development, at least in part, would be required.

TABLE 157

CHARACTERISTICS OF LOCAL AND IMPORTED SUPPLEMENTAL WATER SUPPLIES FOR AREAS IN UPPER SAN JOAQUIN VALLEY RECEIVING SUPPLEMENTAL WATER UNDER PLAN OF IMMEDIATE INITIAL DEVELOPMENT

Area	Local water supplies					Imported water supplies				
	In-season		Out-of-season		Total acre-feet	In-season		Out-of-season		Total acre-feet
	Acre-feet	Per cent	Acre-feet	Per cent		Acre-feet	Per cent	Acre-feet	Per cent	
Average, 8-Year Period, 1921-1929—										
Madera	46,400	42	65,000	58	111,400	94,000	87	14,000	13	108,000
Foothill-Alta	0	0	0	0	0	35,000	100	0	0	35,000
Kaweah	156,000	62	94,800	38	250,800	73,000	71	30,000	29	103,000
Lindsay	13,900	100	0	0	13,900	35,000	100	0	0	35,000
Tule-Deer Creek	47,400	51	44,900	49	92,300	57,000	71	23,000	29	80,000
Earlimart-Delano	1,500	54	1,300	46	2,800	74,000	71	30,000	29	104,000
McFarland-Shafter	37,000	95	1,900	5	38,900	68,000	72	27,000	28	95,000
Magunden-Edison	0	0	0	0	0	6,000	100	0	0	6,000
Lower Kings			No data			25,000	71	10,000	29	35,000
Totals	302,200	59	207,900	41	510,100	467,000	78	134,000	22	601,000
Average, 12-Year Period, 1917-1929—										
Madera	46,400	43	61,600	57	108,000	98,000	92	9,000	8	107,000
Foothill-Alta	0	0	0	0	0	35,000	100	0	0	35,000
Kaweah	159,600	63	95,400	37	255,000	75,000	73	28,000	27	103,000
Lindsay	14,000	100	0	0	14,000	35,000	100	0	0	35,000
Tule-Deer Creek	49,100	53	44,300	47	93,400	59,000	74	21,000	26	80,000
Earlimart-Delano	1,500	56	1,200	44	2,700	77,000	73	28,000	27	105,000
McFarland-Shafter	38,200	96	1,800	4	40,000	70,000	73	26,000	27	96,000
Magunden-Edison	0	0	0	0	0	6,000	100	0	0	6,000
Lower Kings			No data			26,000	74	9,000	26	35,000
Totals	308,800	60	204,300	40	513,100	481,000	80	121,000	20	602,000
Season, 1923-1924—										
Madera	18,300	76	5,700	24	24,000	32,700	100	0	0	32,700
Foothill-Alta	0	0	0	0	0	35,000	100	0	0	35,000
Kaweah	88,000	100	0	0	88,000	17,600	97	600	3	18,200
Lindsay	13,700	100	0	0	13,700	35,000	100	0	0	35,000
Tule-Deer Creek	29,200	99	400	1	29,600	13,600	96	500	4	14,100

Earlimart-Delano	0	0	0	0	0	17,700	97	600	3	18,300
McFarland-Shafter	0	0	0	0	0	16,200	96	600	4	16,800
Magunden-Edison	0	0	0	0	0	6,000	100	0	0	6,000
Lower Kings			No data			6,000	97	200	3	6,200
Totals	149,200	96	6,100	4	155,300	179,800	99	2,500	1	182,300
Season, 1926-1927—										
Madera	53,800	37	89,800	63	143,600	130,400	100	0	0	130,400
Foothill-Alta	0	0	0	0	0	35,000	100	0	0	35,000
Kaweah	171,700	42	233,500	58	405,200	129,100	66	65,800	34	194,900
Lindsay	13,300	100	0	0	13,300	35,000	100	0	0	35,000
Tule-Deer Creek	53,900	37	92,700	63	146,600	100,100	66	51,200	34	151,300
Earlimart-Delano	2,000	43	2,700	57	4,700	130,400	66	66,400	34	196,800
McFarland-Shafter	77,500	95	4,500	5	82,000	118,900	66	60,800	34	179,700
Magunden-Edison	0	0	0	0	0	6,000	100	0	0	6,000
Lower Kings			No data			43,800	66	22,400	34	66,200
Totals	372,200	47	423,200	53	795,400	728,700	73	266,600	27	995,300
Season, 1928-1929—										
Madera	41,800	67	20,300	33	62,100	32,700	100	0	0	32,700
Foothill-Alta	0	0	0	0	0	35,000	100	0	0	35,000
Kaweah	163,800	84	31,000	16	194,800	7,900	100	0	0	7,900
Lindsay	15,500	100	0	0	15,500	35,000	100	0	0	35,000
Tule-Deer Creek	47,600	70	20,600	30	68,200	6,100	100	0	0	6,100
Earlimart-Delano	1,000	53	900	47	1,900	8,000	100	0	0	8,000
McFarland-Shafter	3,900	81	900	19	4,800	7,300	100	0	0	7,300
Magunden-Edison	0	0	0	0	0	6,000	100	0	0	6,000
Lower Kings			No data			2,700	100	0	0	2,700
Totals	273,600	79	73,700	21	347,300	140,700	100	0	0	140,700

In making provision for proper utilization of imported water, consideration should be given to the method of distributing both the "in-season" water falling within the irrigation demand and the excess flows not within the irrigation demand both in and out of season for replenishment of ground water storage. It is proposed that the "in-season" water falling within the irrigation demand be supplied to the irrigated lands by means of surface conduits and ditches in accord with the demand for irrigation water. The water outside of the irrigation demand would be introduced underground by application on absorptive lands for irrigation in greater quantities than net use requirements; through seepage losses from unlined canals and ditches, both existing and proposed; through absorption in streambeds of natural channels; and by the construction of spreading works or by other artificial means of accelerating percolation. The water thus introduced underground would be recovered later by pumping. Areas of ground water storage therefore would require wells and pumping plants as under present conditions of development and utilization of the local water supplies. Under the proposed plan, however, the proportion of the mean seasonal supply which would be obtained by pumping, as well as the average pumping lift, would be materially reduced.

The distribution of the portion of the water supply made available through ground water utilization in each of the absorptive areas of permanent deficiency might be somewhat nonuniform with respect to the degree of its accessibility to meet the requirements over the entire area of a particular unit. However, it is considered that local pumping and conveyance facilities available at present or which could be made available would be used to control and distribute the supply so that all lands to be served in each unit would receive ample water. No detailed plans have been considered for the operation of such local pumping and distribution facilities under the initial State Water Plan. The plan as formulated provides the required water supply for each unit as a whole, leaving the detailed plans of local distribution to later consideration with local interests. However, sufficient investigations have been made in each area to demonstrate that the water supplies furnished under the initial plan of development could be distributed and utilized to meet the requirements of all developed lands to be served in each area, by utilization of present pumping and conveyance facilities and practicable additions or enlargements thereof.

Operation and Accomplishments in San Joaquin Delta Region—Under the immediate initial development in the San Joaquin River Basin, the relief of the developed lands in the San Joaquin Delta and adjacent upland areas would be effected through the operation of the initial storage unit of the State Water Plan in the Sacramento River Basin, namely Kennett Reservoir. Detailed data as to the physical features and operation and accomplishments of this initial storage unit are presented in other reports.* In addition to meeting the water requirements in the Sacramento Valley, this reservoir would be operated to provide regulated supplies to supplement the unregulated inflow into

*Bulletin 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.
Bulletin 26, "Sacramento River Basin," Division of Water Resources, 1931.

the Sacramento-San Joaquin Delta from both the Sacramento and San Joaquin river systems and fully meet the needs of the entire delta, the adjacent delta uplands and areas in the upper San Francisco Bay region.

Under the method of operation designated as "Method II" in the reports cited, the operation and accomplishments of Kennett Reservoir under the plan of immediate initial development are briefly summarized as follows:

Space would have been reserved in the reservoir for flood control, and stored water would have been released in such manner as to supplement the flows from unregulated streams in the Sacramento River Basin or those regulated by present developments, from return irrigation waters in the Sacramento Valley, and from inflows to the Sacramento-San Joaquin Delta from the San Joaquin River Basin under conditions with the immediate initial development of the State Water Plan in that basin in operation, to make supplies availabile for irrigation, navigation, salinity control and the generation of power. The following would have been accomplished:

1. The space reserved in the reservoir each season for flood control would have prevented flood flows from exceeding 125,000 second-feet at Red Bluff.
2. A navigable depth on the Sacramento River of five to six feet would have been maintained from the city of Sacramento to Chico Landing, with a substantial increase in present depths from Chico Landing to Red Bluff.
3. Irrigation demands on the Sacramento River above Sacramento would have been supplied, without deficiency, up to 6000 second-feet maximum draft in July. A full irrigation supply would have been furnished in all years to all lands along the Sacramento River above the delta. There would have been over 700,000 acre-feet more water available, in accordance with the irrigation schedule, for these lands in 1924.
4. An irrigation supply, without deficiency, would have been furnished the Sacramento-San Joaquin Delta for its present requirements.
5. A fresh water flow of not less than 3300 second-feet would have been maintained past Antioch into Suisun Bay, controlling salinity to the lower end of the Sacramento-San Joaquin Delta.
6. A water supply, without deficiency, would have been made available in the delta for the developed industrial and agricultural areas along the south shore of Suisun Bay in Contra Costa County.
7. An annual average of 1,591,800,000 kilowatt hours of hydroelectric energy would have been generated, incidental to other uses.

The water that would have been made available in the channels of the Sacramento-San Joaquin Delta to meet the immediate requirements within the delta and the adjacent areas requiring immediate relief, under the plan of immediate initial development with Kennett and Friant reservoirs operated as previously set forth, has been estimated by means of the detailed month by month studies of the operation of

TABLE 158

SEASONAL NET RUN-OFF FROM SAN JOAQUIN RIVER BASIN INTO SAN JOAQUIN DELTA FOR THE PERIOD 1917-1929 UNDER CONDITIONS OF IRRIGATION AND STORAGE DEVELOPMENTS AS OF 1929, AND MUNICIPAL DIVERSIONS AS OF 1940, WITH DIVERSIONS FROM SAN JOAQUIN RIVER UNDER PLAN OF IMMEDIATE INITIAL DEVELOPMENT

Season	Run-off, in acre-feet							Pumping diversions from San Joaquin River, between Newman and Vernalis, in acre-feet	Run-off into San Joaquin Delta, in acre-feet
	San Joaquin River, at Newman	Tuolumne River, at confluence with San Joaquin River	Stanislaus River, at confluence with San Joaquin River	Calaveras River, at Jenny Lind	Mokelumne River, below Woodbridge	Dry Creek, near Ione	Cosumnes River, below Michigan Bar		
1917-1918	959,100	1,002,100	644,100	212,200	439,000	46,200	220,700	89,300	3,434,100
1918-1919	703,500	840,000	497,400	97,300	484,100	61,100	258,300	89,300	2,852,400
1919-1920	447,900	819,000	436,900	83,200	384,400	34,100	168,500	89,300	2,284,700
1920-1921	913,900	1,394,600	930,100	221,900	646,300	108,000	404,200	89,300	1,529,700
1921-1922	2,180,100	1,908,600	1,148,100	220,500	768,600	86,300	423,200	89,300	6,646,100
1922-1923	1,165,700	1,241,800	841,100	181,100	600,800	135,000	435,500	89,300	4,511,700
1923-1924	227,500	493,700	147,600	23,700	326,800	3,300	42,200	89,300	1,175,500
1924-1925	488,600	1 092,800	884,000	159,100	475,700	83,700	255,900	89,300	3,350,500
1925-1926	460,400	729,200	432,200	65,300	416,900	32,200	146,400	89,300	2,193,300
1926-1927	1,125,800	1,276,900	1,031,300	181,000	606,400	96,100	449,800	89,300	4,678,000
1927-1928	590,100	1,077,300	743,700	130,400	570,600	69,100	313,100	89,300	3,405,000
1928-1929	281,800	658,400	248,600	41,000	401,500	22,200	113,400	89,300	1,677,600
Mean for period, 1917-1929	795,400	1,044,500	665,400	134,700	510,100	64,800	269,300	89,300	3,394,900

these reservoirs and the inflow from the tributaries of the Sacramento and San Joaquin rivers under present conditions of development. The utilization of the surplus and grass land waters of the San Joaquin River by regulation in Friant Reservoir under the plan of immediate initial development would have the effect of reducing the flow into the San Joaquin River Delta. Based upon the proposed plan of operation with diversions from Friant Reservoir as previously presented for the plan of immediate initial development, the flow of the San Joaquin River System into the San Joaquin Delta is shown for each season during the period 1917–1929 in Table 158. The quantities shown in this table, except for the modifications of flow resulting from the proposed operation of Friant Reservoir, are based upon irrigation and storage developments as of 1929 and on municipal diversions as of 1940. By comparing the amounts of seasonal run-off into the delta shown in Table 7 in Chapter II, the amount of reduction in seasonal inflow resulting from the proposed plan of immediate initial development may be ascertained. The average seasonal reduction in delta inflow from the San Joaquin River Basin during that period would have amounted to 385,000 acre-feet.

The net inflow into the Sacramento-San Joaquin Delta from both the Sacramento and San Joaquin river systems, the immediate water requirements of the delta and adjacent areas to be served therefrom and the surplus of supply over requirements that would have flowed into Suisun Bay under the plan of immediate initial development are shown for each year of the 10-year period 1919–1929 in Table 159.

The water requirements of the developed areas in the delta uplands between Vernalis and Antioch, which are now supplied by pumping from the delta channels, are not set up under the requirements shown in Table 159. The present requirements for these uplands have been taken care of by deducting the net use from the quantities of inflow from the San Joaquin River Basin set forth in Table 158. The net inflows from the San Joaquin Valley in Table 159 differ from those in Table 158 by the amounts deducted for present net use requirements in the delta uplands which amounts total about 93,000 acre-feet annually.

The data set forth in Table 159 show not only that ample water would have been available in the delta under the plan of immediate initial development to fully satisfy the requirements in the delta and the adjacent areas but also a substantial surplus over and above all requirements. The bulk of this surplus would occur during the winter and spring months but there would have been considerable amounts of surplus water in most years of this period during eight or nine months. The amount of surplus water above all requirements and the flow into Suisun Bay are shown by months for the years of maximum and minimum run-off during the period 1919–1929 and the average amounts for the whole period in Table 160. The excess flows into Suisun Bay combined with the minimum flows provided for controlling saline invasion at the lower end of the delta would result in the continuous maintenance of fresh water in the delta channels free from saline invasion from the bay, would improve salinity conditions in Suisun Bay and make them practically equivalent to those which would have obtained under natural conditions before the expansion of irrigation, storage and reclamation development in the Sacramento and San Joaquin river basins.

TABLE 159

ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY UNDER OPERATION OF UNITS FOR IMMEDIATE INITIAL DEVELOPMENT OF STATE WATER PLAN IN GREAT CENTRAL VALLEY, 1919-1929

Year	Net flow into delta, in acre-feet[1]			Requirements from net flow into delta, in acre-feet				Surplus water above all requirements, in acre-feet	Total flow into Suisun Bay, in acre-feet
	From Sacramento Valley	From San Joaquin Valley[2]	Total from both valleys	Total gross allowance for delta	Salinity control to lower end of delta	Industrial and irrigation use in developed areas along south side of Suisun Bay	Total		
1919	16,340,000	2,769,000	19,109,000	1,083,000	2,389,000	44,000	3,516,000	15,593,000	17,982,000
1920	12,625,000	2,312,000	14,937,000	1,083,000	2,395,000	44,000	3,522,000	11,415,000	13,810,000
1921	22,041,000	4,440,000	26,481,000	1,083,000	2,389,000	44,000	3,516,000	22,965,000	25,354,000
1922	19,755,000	6,997,000	26,752,000	1,083,000	2,389,000	44,000	3,516,000	23,236,000	25,625,000
1923	12,339,000	4,116,000	16,455,000	1,083,000	2,389,000	44,000	3,516,000	12,939,000	15,328,000
1924	7,302,000	1,108,000	8,410,000	1,083,000	2,395,000	44,000	3,522,000	4,888,000	7,283,000
1925	15,617,000	3,432,000	19,049,000	1,083,000	2,389,000	44,000	3,516,000	15,533,000	17,922,000
1926	14,819,000	2,190,000	17,009,000	1,083,000	2,389,000	44,000	3,516,000	13,493,000	15,882,000
1927	24,714,000	4,688,000	29,402,000	1,083,000	2,389,000	44,000	3,516,000	25,886,000	28,274,000
1928	17,216,000	3,295,000	20,511,000	1,083,000	2,395,000	44,000	3,522,000	16,989,000	19,384,000
Averages	16,277,000	3,535,000	19,812,000	1,033,000	2,391,000	44,000	3,518,000	16,294,000	18,685,000

[1] Includes regulated water from Kennett, Friant and existing reservoirs, unregulated run-off and return waters.

[2] Quantities shown for the inflows from the San Joaquin Valley differ from those in Table 158 in that the net use requirements of the delta uplands from Vernalis to Antioch supplied by pumping from the delta channels have been deducted from the amounts of run-off shown in Table 158 to obtain the quantities shown in Table 159. The present net use requirements for these delta uplands total about 93,000 acre-feet annually.

TABLE 160

MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY UNDER OPERATION OF IMMEDIATE INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY, 1919-1929

Month	Year of maximum run-off, 1927		Year of minimum run-off, 1924		Average for period 1919-1929	
	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet
January	2,521,000	2,724,000	613,000	816,000	1,794,000	1,997,000
February	7,514,000	7,697,000	1,038,000	1,228,000	3,142,000	3,328,000
March	3,883,000	4,086,000	533,000	736,000	2,674,000	2,877,000
April	4,066,000	4,262,000	462,000	658,000	2,537,000	2,733,000
May	2,904,000	3,107,000	64,000	267,000	2,174,000	2,377,000
June	1,853,000	2,049,000	10,000	206,000	1,088,000	1,284,000
July	239,000	442,000	0	203,000	201,000	404,000
August	118,000	321,000	0	203,000	87,000	290,000
September	177,000	373,000	63,000	259,000	150,000	346,000
October	348,000	551,000	364,000	567,000	350,000	553,000
November	1,179,000	1,375,000	762,000	958,000	888,000	1,084,000
December	1,084,000	1,287,000	979,000	1,182,000	1,209,000	1,412,000
Totals	25,886,000	28,274,000	4,888,000	7,283,000	16,294,000	18,685,000

Economic and Financial Aspects—The capital cost of the plan for immediate initial development for the San Joaquin Valley, based on State financing and including general expense and cost of water rights as set forth in Table 149, is estimated at $50,400,000. This figure does not include any portion of the cost for storage development proposed in the plan for immediate initial development in the Sacramento River Basin. As previously stated, the initial storage unit (Kennett Reservoir) in the Sacramento River Basin is considered essential to the immediate initial plan of development in the San Joaquin River Basin because it is required to provide supplemental supplies for the Sacramento-San Joaquin Delta and adjacent areas not only to meet present deficiencies therein but also to replace water of the San Joaquin River diverted at Friant. It is believed that no transfer of water from the San Joaquin River to the upper San Joaquin Valley would be possible of effectuation without provision of full supplies for the delta and adjacent uplands and the removal of the salinity menace in the delta. The consideration of the financial aspects of the plan for immediate initial development in the San Joaquin River Basin must be combined with that in the Sacramento River Basin, as the initial units in both basins are interdependent and interrelated and together comprise a unified project of coordinate development for the immediate initial State Water Plan in the entire Great Central Valley.

The gross annual cost of the units for immediate initial development in the San Joaquin Valley would vary with the amortization period and interest rate on bonds. The costs for three periods of amortization and with an assumed interest rate of 4½ per cent with State financing are given below. These figures include interest, amortization of capital investment on a 4 per cent sinking fund basis, depreciation of physical works and operation and maintenance expense.

Amortization period in years	*Gross annual cost*
40	$3,796,000
50	3,603,000
70	3,417,000

The foregoing figures include the amortization of the capital investment of $1,500,000 in Friant power plant in ten years.

The anticipated direct revenues from the project would be obtained from:

1. Sale of electric energy.
2. Sale of water.

Electrical energy would be generated at the Friant Power Plant, a 30,000 kilovolt ampere installation. On the average, 105,000,000 kilowatt-hours would be generated annually. It is estimated that the value of this power at the switchboard would be 3.5 mills per kilowatt-hour. The annual revenue on this basis would be $367,000. The unit value of 3.5 mills is based on the cost of producing an equivalent amount of electric energy of the same characteristics with a steam electric plant located in the area of consumption, taking into account the cost of transmission and transmission losses from the point of generation to the load center. The annual revenue from power is the total amount which would be realized when the energy output is fully utilized, and it is assumed herein that arrangements would be made with producing and marketing agencies to plan their development so that the entire output from Friant power plant would be absorbed into the power market at the time of its completion.

The revenues which could be expected from the sale of water, at main canal side, to the lands in production, adjudged in need of immediate relief under the State plan for the upper San Joaquin Valley, have been estimated on the basis of the ability of the producing lands to pay for irrigation water by consideration of the following controlling factors:

1. Acreage of various crops.
2. Permissible annual charges for water at the land for various crops.
3. Characteristics of imported water supply.
4. Cost of distributing imported water, including cost of pumping to areas above main canals.
5. Depths to ground water.
6. Cost of pumping ground water contributed by both local and imported supplies.

Table 161 sets forth, for the several areas considered as having a permanent deficiency in water supply, the acreage in various crops in 1929.

The permissible annual charges per acre for water delivered at the land for various crops are given in Table 162. These are taken from Table 1, page 14 of Bulletin No. 34, "Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley," Division of Water Resources, 1930. The figures set forth are considered permissible for a full supply of water delivered at the land on which it is to be used and

TABLE 161

CROP CLASSIFICATION IN IRRIGATED AREAS OF PERMANENT DEFICIENCY IN WATER SUPPLY, FOR 1929, IN ACRES

Area	Citrus	Deciduous and olives	Grapes	Grain	Alfalfa	Field crops	Cotton	Pasture	Truck	Total
Madera Ground Water Unit		8,200	25,300		16,200	2,000	27,400	1,300	600	81,000
Foothill District	3,600	3,000	4,400							11,000
Rim lands in Alta District	800	1,700	2,500							5,000
Kaweah Ground Water Unit	12,000	23,500	22,000	2,000	38,000	6,000	14,500	*3,900	1,000	122,900
Lindsay Ground Water Unit	13,000	4,000	2,800		500	400	1,200		100	22,000
Tule-Deer Creek Ground Water Unit	3,700	5,800	8,000	1,100	9,500	2,400	34,000	5,200	500	70,200
Area east of Tule-Deer Creek Unit	4,000	600	400							5,000
Earlimart-Delano Ground Water Unit	500	1,000	13,000		1,000	1,000	14,000			30,500
McFarland-Shafter Ground Water Unit		8,400	11,700		10,000	7,500	12,200			49,800
Edison-Magunden Unit	1,000	1,600								2,600
Totals	38,600	57,800	90,100	3,100	75,200	19,300	103,300	10,400	2,200	400,000

* An additional 5,600 acres of pasture is not included as an area of deficiency.

are intended to include all items such as interest and principal payments on capital expenditures for irrigation works and water supply, costs of maintenance and operation of irrigation works, as ordinarily understood, and supplemental pumping. These figures are somewhat lower than the excess of income over all other costs of producing and harvesting the crops, including interest on the capital investment, as estimated in Bulletin No. 34. The difference varies from 10 to 50 per cent.

TABLE 162

PERMISSIBLE ANNUAL CHARGES FOR IRRIGATION WATER AT THE LAND IN UPPER SAN JOAQUIN VALLEY, FOR VARIOUS CROPS

Data from Table 1, Bulletin No. 34, "Permissible annual charges for irrigation water in Upper San Joaquin Valley," Division of Water Resources, 1930

Crop	Permissible annual charge, per acre
Oranges	$30 00
Deciduous fruits	7 50
Grapes, more common varieties	5 00
Grapes, more profitable table varieties	7 50
Grain, Tulare Lake lands, only	6 00
Cotton	7 50
Alfalfa	8 00
Miscellaneous crops	5 00

The permissible total charges for irrigation water at the land in the areas of permanent deficiency in water supply have been estimated by applying unit charges set forth in Table 162, to each of the various crops set forth in Table 161. They are set forth in Table 163. Under conditions of immediate initial development, a small amount of expansion in the present irrigated areas devoted to the more valuable crops is quite probable. Therefore permissible total charges with the citrus area increased by 25 per cent also are given in the tabulation. Since the permissible unit charges are from 10 to 50 per cent less than the excess of income over all other costs of producing and harvesting the crops as estimated in Bulletin No. 34, total permissible charges for irrigation water with an increase of 25 per cent also are set forth.

TABLE 163

PERMISSIBLE TOTAL CHARGES FOR IRRIGATION WATER AT THE LAND IN AREAS OF PERMANENT DEFICIENCY IN WATER SUPPLY IN UPPER SAN JOAQUIN VALLEY

Crop	Area irrigated in 1929, in acres	Permissible unit charge per acre	Total permissible charge	Total permissible charge, with a 25 per cent increase in citrus areas	Total permissible charge, based on 1929 irrigated areas, and an increase of 25 per cent in permissible unit charges
Citrus fruits	38,600	$30 00	$1,158,000	$1,448,000	$1,448,000
Deciduous fruits and olives	57,800	7 50	433,000	433,000	541,000
Grapes	90,100	7 50	676,000	676,000	845,000
Alfalfa	75,200	8 00	602,000	602,000	752,000
Cotton	103,300	7 50	775,000	775,000	969,000
Miscellaneous	35,000	5 00	175,000	175,000	219,000
Totals	400,000	------------	$3,819,000	$4,109,000	$4,774,000

The characteristics of the water supply which could have been made available to the areas of permanent deficiency in water supply for different periods and seasons from 1917 to 1929, segregated as to its time of occurrence within or without the irrigation season, has been set forth in Table 157. Table 164 recapitulates and combines the average annual amounts of in-season and out of season water available from local and imported sources for the 8-year period 1921–1929. The corresponding supplies for the minimum season 1923–1924 also are set forth.

TABLE 164

WATER SUPPLIES AVAILABLE FOR AREAS OF PERMANENT DEFICIENCY UNDER CONDITIONS OF IMMEDIATE INITIAL DEVELOPMENT

Area	Average seasonal water supply for 8-year period, 1921-1929, in acre-feet					
	In-season water			Out-of-season water		
	Local supply	Imported supply	Totals	Local supply	Imported supply	Totals
Madera	46,400	94,000	140,400	65,000	14,000	79,000
Alta-Foothill	0	35,000	35,000	0	0	0
Kaweah	156,000	73,000	229,000	94,800	30,000	124,800
Lindsay	13,900	35,000	48,900	0	0	0
Tule-Deer Creek	47,400	57,000	104,400	44,900	23,000	67,900
Earlimart-Delano	1,500	74,000	75,500	1,300	30,000	31,300
McFarland Shafter	37,000	68,000	105,000	1,900	27,000	28,900
Magunden-Edison	0	6,000	6,000	0	0	0
Totals	302,200	442,000	744,200	207,900	124,000	331,900
	Water supply for minimum season 1923-24, in acre-feet					
Totals	149,200	173,800	323,000	6,100	2,300	8,400

The costs of distributing both the imported and local supplies are assumed as $1.00 per acre-foot for in-season water and $0.15 per acre-foot for out of season water. The latter figure is on the basis of operating costs only, assuming that the former figure includes all fixed charges on the distribution system.

In addition to areas to be served imported in-season water by gravity distribution from the San Joaquin River-Kern County Canal, there are areas of permanent deficiency requiring regulated supplies of in-season water, which lie at an elevation above the canal and would be served by local pumping projects. These higher areas are fairly of in-season water, which lie at an elevation above the canal and would be 66 feet and the average seasonal quantity to be delivered about 80,000 acre-feet. The additional cost of distribution above that allowed for gravity distribution is estimated at $2.00 per acre-foot or $0.03 per foot acre-foot.

One-third of the in-season water, all of the out of season water and one-fifth of all water pumped from wells are considered as contributions to ground water. With an annual net use requirement of two acre-feet per acre, it is assumed that the main canal delivery for areas irrigated entirely by a surface supply would be three acre-feet per acre and, for areas served entirely by wells and pumping plants, would be 2.5 acre-feet per acre. The unit costs of ground water pumping have been based on analyses presented in Chapter VI, the results of which are set forth in detail in Table 101. The general average unit values for estimating the cost of ground water pumping in the upper San Joaquin Valley have been determined as two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for energy charges. The average depths to ground water in absorptive areas of permanent deficiency are set forth in Table 165 for the fall of 1921 and the fall of 1929. The total pumping lifts would exceed these depths by the amount of well drawn down during the period of operation, for which full allowance has been made in estimating pumping costs.

TABLE 165

AVERAGE DEPTHS TO GROUND WATER IN AREAS OF PERMANENT DEFICIENCY IN UPPER SAN JOAQUIN VALLEY

Ground water unit	Gross area, in square miles	Average depth to ground water, in feet	
		Fall of 1921	Fall of 1929
Madera	343	23.9	35.2
Kaweah	468	19.2	37.2
Tule-Deer Creek	373	39.5	62.1
Earlimart-Delano	150	84.2	117.6
McFarland-Shafter	310	42.3	67.1
Total area and weighted average depths	1,644	35.0	55.4

As shown by Plate LXXII, the accumulated net depletion of ground water during the 8-year period 1921–1929 totaled 2,560,000 acre-feet, resulting in an average weighted lowering in ground water levels of 20 feet in absorptive areas of permanent deficiency in the upper San Joaquin Valley. This depletion was at the average rate of 128,000 acre-feet per foot of lowering.

For conditions of irrigation development and water supply utilization as of 1929, the total net use requirement for the areas of permanent deficiency, comprising about 400,000 acres of developed lands excluding the lower Kings River area, is estimated at 917,000 acre-feet per season. The average seasonal local and imported supplies available for these areas, for the 8-year period 1921–1929, would have been 744,000 acre-feet of in-season water and 332,000 acre-feet of out of season water or a total of 1,076,000 acre-feet. The average supply would have exceeded the 1929 net use requirements by 159,000 acre-feet per season which excess amount would have been available for underground storage. Based upon the relation between depletion and ground water lowering which actually occurred from 1921 to 1929, namely 128,000 acre-feet per foot of lowering, it is estimated that an average seasonal accretion to ground water storage of 159,000 acre-feet would result in an average seasonal rise of 1.24 feet varying from 0.4 feet in the Madera unit to 3.8 feet in the Earlimart-Delano unit, with the average amounts of regulated and local water supplies as of the period 1921–1929 and with net use requirements as of 1929.

With the average depths to ground water as of 1929, and allowing for 20 feet of well drawn down, the total average lift for ground water pumping would be 75 feet. With ten years operation of the plan and an average seasonal water supply equal to the average for the eight-year period 1921–1929, the average lift would be reduced to 63 feet; and with 20 years of similar operation and water supply, to 50 feet.

Based upon the foregoing data on water supply, pumping lifts, and unit costs for distribution and pumping, the annual cost of distribution and application of water from main canal side to the land is estimated as follows: The annual cost of distribution of in-season water at $1.00 per acre-foot would be $744,000; of out of season water at $0.15 per acre-foot, $50,000. The additional cost of lifting a surface supply of 80,000 acre-feet through lifts averaging 66 feet above San Joaquin River-Kern County Canal at $2.00 per acre-foot would be $160,000. With the 744,000 acre-feet of in-season water distributed on a basis of three acre-feet per acre to serve 248,000 acres, the remaining area of deficiency to be served by ground water pumping would be 152,000 acres. With a pumping requirement of 2.5 acre-feet per acre, the average quantity to be pumped would be 380,000 acre-feet per season. At $0.03 per foot acre-foot, the annual energy charge with the water levels as of 1929 would be $855,000. With the decreased pumping lift resulting from an average seasonal rise in ground water levels of 1.24 feet from replenishment of the underground reservoirs, the energy charge after 10 years of operation would be $718,000 and after 20 years $570,000. For the minimum season, 323,000 acre-feet of in-season water would have been available. If distributed on a basis of three acre-feet per acre, the remaining area to be served by ground water pumping in that season would have been 292,000 acres. With a pumping requirement of 2.5 acre-feet per acre, the maximum required installed capacity would be 730,000 acre-feet for a lift of 75 feet. There would undoubtedly be some shortage of installed pumping capacity in the peak months of a season of minimum yield, although the total seasonal quantity pumped might closely approach the requirement. The maximum pumping installation is estimated on a basis of 500,000 acre-feet or 68 per cent of the peak requirement in the season of 1923–1924. Based upon this amount and a lift of 75 feet, the total fixed charge on wells and pumping plants at $0.02 per foot acre-foot would be $750,000.

Table 166 summarizes the data previously presented on annual costs for distribution and utilization of water from main canal side to the land and the permissible annual charges for water at the land; and sets forth the resulting estimated limits of permissible annual charges for water at main canal side. These are presented on three different assumptions as to ground water conditions and for three different assumptions as to permissible charges for water at the land.

It can be readily observed that as the depth to ground water decreases, the margin between production costs and returns increases rapidly. When considered over longer periods, during which the average seasonal in-flow would be much greater than assumed in the analysis, the margin would be considerably larger. Probably the rise for a twenty-year period would be twice that indicated by applying the average seasonal supply for the eight-year period. In addition to the reductions shown in energy charges with the rise in ground water, there also would be some reduction in fixed charges after the useful life of the

TABLE 166

LIMIT OF PAYMENT FOR IMPORTED WATER AT MAIN CANAL SIDE FOR AREAS OF PERMANENT DEFICIENCY IN WATER SUPPLY IN UPPER SAN JOAQUIN VALLEY

Based on the Average Seasonal Water Supply for the 8-year Period, 1921-1929

Item	With ground water conditions as of 1929	With ground water conditions after 10 years of operation, and an average seasonal water supply equal to that of the 8-year period 1921-1929	With ground water conditions after 20 years of operation, and an average seasonal water supply equal to that of the 8-year period 1921-1929
Distribution of in-season water	$744,000	$744,000	$744,000
Additional cost for pumping a portion of the supply to areas above canal	160,000	160,000	160,000
Distribution of out-of-season water	50,000	50,000	50,000
Fixed charges on wells and pumping plants	750,000	750,000	750,000
Energy charges for pumping ground water	855,000	718,000	570,000
Total annual cost of distribution and utilization	$2,559,000	$2,422,000	$2,274,000
Total permissible annual charges for water at land based on area irrigated in 1929	$3,819,000	$3,819,000	$3,819,000
Limit of payment for imported water at main canal side	1,260,000	1,397,000	1,545,000
Per acre-foot (566,000 acre-feet)	2.23	2.47	2.73
Total permissible annual charges for water at land based on irrigated acreage in 1929 but with a 25 per cent increase in citrus areas	$4,109,000	$4,109,000	$4,109,000
Limit of payment for imported water at main canal side	1,550,000	1,687,000	1,835,000
Per acre-foot (566,000 acre-feet)	2.74	2.98	3.24
Total permissible annual charges for water at land increased 25 per cent, based on area irrigated in 1929	$4,774,000	$4,774,000	$4,774,000
Limit of payment for imported water at main canal side	2,215,000	2,352,000	2,500,000
Per acre-foot (566,000 acre-feet)	3.91	4.16	4.42

originally installed pumping equipment expired, as all replacements would be installed for lower lifts. Fixed charges used in obtaining the $0.02 per foot acre-foot value have been based on an average life of 18 years for the entire pumping plant installation. For shorter periods, some exchange of motors for smaller capacities or the removal of a bowl from the pumps may result in small reductions in fixed charges.

From all of the foregoing data it is concluded that $3.00 per acre-foot at main canal side is a reasonable estimate of a permissible average charge for imported water for the areas in the upper San Joaquin Valley receiving such a supply under the initial State Water Plan. Although the analyses used in arriving at this value have been based on the ability of the producers of the various crops to pay for imported water, it is not suggested that water charges be made to the individual on a crop basis. Differential rates based on anything except character of service would be difficult to apply. Much of the citrus area is above the importation canal on relatively impervious soils so that fully regulated service would be required. This in turn requires primary water storage at Friant Reservoir. Such primary service could be put on a higher rate and supplied mainly to citrus areas. In-season secondary water in accord with the irrigation demand that would directly replace ground water pumping, chiefly for general crops, would have a considerably lower rate. Out of season water or that in excess of the irrigation demand to be utilized for raising ground water levels and applicable for irrigation use only by pumping would carry a still lower rate commensurable with the cost and value of such service. No final determination has been made in this report of charges for imported water based upon character of service. However, for the purpose of presenting one possible basis for water charges with different rates as related to character of service, a tentative set-up is shown in Table 167. Total charges shown in the table are based upon the average seasonal supply available for importation for the 8-year period 1921–1929 and result in an average rate of $3.15 per acre-foot.

TABLE 167

TENTATIVE CHARGES FOR IMPORTED WATER AT MAIN CANAL SIDE FOR AREAS IN UPPER SAN JOAQUIN VALLEY, BASED ON CHARACTER OF SERVICE

Character of service	Average seasonal yield from Friant Reservoir, for the 8-year period 1921-1929, in acre-feet	Tentative charges for imported water	
		Rate per acre-foot	Total
Primary water	138,000	$8 00	$1,104,000
Secondary, in-season, water	329,000	2 00	658,000
Secondary, out-of-season, water	134,000	1 00	134,000
Totals	601,000	$3 15	$1,896,000

In addition to the units of the San Joaquin Valley for which costs and revenues have been presented, the immediate initial development in the entire Great Central Valley provides for the construction of Kennett Reservoir on the Sacramento River and the Contra Costa County Conduit to deliver water from the delta to the upper San Francisco Bay region. Discussion of these units including plans of development and estimates of costs and revenues have been published in other reports.* Electrical energy would be generated at the power plants of the Kennett Reservoir, with an average annual output of 1,591,800,000 kilowatt hours. It is estimated that this power would have a value at the switch board of 2.65 mills per kilowatt hour to yield an annual revenue of $4,218,000. About 43,500 acre-feet annually could be diverted from the delta by the Contra Costa County Conduit. It is estimated that a revenue of $300,000 per year could be obtained from the sale of this water. In order to control salinity in the Sacramento-San Joaquin Delta and furnish a full supply to the lands under irrigation along the Sacramento River and in the delta, an average annual release of about 420,000 acre-feet of stored water from Kennett Reservoir would be required. The estimated average cost of such stored water, with Kennett Reservoir operated entirely for irrigation purposes and with proper allowances for power credit, is $1.00 per acre-foot. Therefore, it is

*Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.
Bulletin No. 28, "Economic Aspects of a Salt Water Barrier," Division of Water Resources.

estimated that the Sacramento Valley and delta interests might be reasonably expected to make an average annual payment of $420,000 for stored water furnished to them from Kennett Reservoir. No deductions have been made for this possible revenue, however, in obtaining the net annual cost in Table 168, but it is included in the financial analyses set forth in Table 169.

The capital and gross annual costs and anticipated revenues under the plan of immediate initial development in the Great Central Valley are presented in Table 168. The annual costs include operation and maintenance charges, interest at 4½ per cent per annum, amortization on a forty-year sinking fund basis at four per cent, and depreciation on a four per cent sinking fund basis with different lengths of service for the various elements of each unit. The revenues are estimated as the total amounts which would be realized when the supplies provided are fully utilized and sold at the unit prices indicated.

TABLE 168

COSTS AND REVENUES FOR IMMEDIATE INITIAL DEVELOPMENT OF STATE WATER PLAN IN GREAT CENTRAL VALLEY

Item	Capital cost	Gross annual cost	
Capital and Annual Costs—			
Kennett reservoir and power plant	$84,000,000	$5,297,000	
Contra Costa County conduit	2,500,000	300,000	
Friant reservoir and power plant	15,500,000	1,062,000	
Madera canal	2,500,000	213,000	
San Joaquin River-Kern County Canal	27,300,000	2,225,000	
Magunden-Edison Pumping system	100,000	18,000	
Water rights and general expense	7,000,000	389,000	
Total	$138,900,000	$9,504,000	$9,504,000
Annual Revenues—			
Electric energy sales:			
1,591,800,000 kilowatt-hours at $0.00265	$4,218,000		
105,000,000 kilowatt-hours at $0.0035	367,000		
Total electric energy sales		$4,585,000	
Water sales:			
600,000 acre-feet for upper San Joaquin Valley, based on average for twelve-year period, 1917-1929, at $3.00 per acre-foot	$1,800,000		
43,500 acre-feet for Contra Costa County conduit at $6 90 per acre-foot	300,000		
Total water sales		$2,100,000	
Total revenues, electric energy and water		$6,685,000	$6,685,000
Net Annual Cost in Excess of Revenues			$2,819,000

It may be seen from the foregoing tabulation that, with State financing at 4½ per cent interest and amortization of the capital investment in 40 years, the gross annual cost exceeds the anticipated revenues from the sale of power and water from the project by $2,819,000. If the possible revenue from the sale of stored water for use in the Sacramento Valley and Sacramento-San Joaquin Delta be considered, the excess of gross annual cost above anticipated revenues would be reduced about $420,000.

Many interests, other than those who actually would receive water in the upper San Joaquin Valley, also would be greatly benefited. In the Sacramento Valley there would be many beneficiaries. The reduction of floods on the Sacramento River would furnish an additional degree of protection to the overflow lands in the Sacramento Flood Control Project, resulting in a reduction of potential annual flood damages.

The Federal and State governments, the various districts and individual landowners would be interested in this feature. The improvement of navigation on the Sacramento River for 190 miles above the city of Sacramento is a feature in which the Federal government would be interested and is a basis upon which it might be expected to participate financially. The furnishing of a full supply to the lands under irrigation along the Sacramento River and in the Sacramento-San Joaquin Delta would be of great benefit to the lands above the city of Sacramento in their being assured of an adequate supply in all years without being curtailed in their diversions because of navigation requirements or the possibility of being enjoined by the water users below the city of Sacramento. Some of the lands above Sacramento also would be benefited in all years, and particularly in dry years, by decreased pumping charges due to higher water levels in the Sacramento River channel. This would be a substantial sum in dry years. The city of Sacramento would be benefited as to the quality of its water supply, which it obtains from the Sacramento River. In all years, a flow of not less than 5000 second-feet would be passing the intake of its pumping plant. In 1920, the mean flow during one 24-hour period in July was as low as 440 second-feet. On this day there was a reversal of flow upstream amounting to a maximum of 2300 second-feet.

The control of salinity to the lower end of the Sacramento-San Joaquin Delta would relieve the salt water menace in that area and would furnish the irrigated lands a fresh water supply at all times. The furnishing of an adequate and suitable water supply to the industrial and agricultural areas along Suisun Bay not only would benefit the immediate area, but also the metropolitan areas of Oakland and San Francisco.

The relief afforded the upper San Joaquin Valley by the consummation of this plan would prevent the retrogression of a large area of agricultural land. The maintenance of these lands in production would prevent a loss of taxable wealth in the southern valley counties, help to restore agricultural credit, maintain and increase business in communities of the affected areas and between those areas and the large metropolitan centers, and assist in the protection of public utility and banking investments in these areas.

It is believed that direct contributions by the State and Federal governments might be reasonably anticipated to meet a portion of the cost of the development, in amounts justified by national and state-wide benefits. It is possible that, in financing the project, funds could be borrowed at a lower rate of interest, particularly if arrangements were made for a loan from the Federal government. It is possible also that the State could obtain money at an interest rate of less than 4½ per cent. The amortization period might be extended from 40 years to 50, 60 or 70 years and thereby reduce the annual costs. The present legal limitation for State bonds is 75 years.

Analyses were made of many plans of financing the immediate initial project based on various interest and sinking fund rates, amortization periods and Federal and State contributions. For purposes of comparison, fourteen of these analyses are summarized in Table 169. In these analyses, a revenue of $420,000 annually is assumed from sale of water to the Sacramento Valley and Sacramento-San Joaquin Delta.

TABLE 169

FINANCIAL ANALYSES OF PLAN OF IMMEDIATE INITIAL DEVELOPMENT GREAT CENTRAL VALLEY PROJECT WITH VARIOUS ASSUMED INTEREST RATES, AMORTIZATION PERIODS AND STATE AND FEDERAL CONTRIBUTIONS

Basis of financing	Capital cost	Gross annual cost	Annual direct revenue from water and power sales[1]	Net annual cost (—), or return (+)
Without Direct Federal or State Contributions—				
Plan 1. Interest at 4½ per cent and 40-year amortization on a 4 per cent sinking fund basis	$138,900,000	$9,504,000	$7,105,000	—$2,399,000
Plan 2. Interest at 4½ per cent and 50-year amortization on a 4 per cent sinking fund basis	138,900,000	8,960,000	7,105,000	—1,855,000
Plan 3. Interest at 4½ per cent and 70-year amortization on a 4 per cent sinking fund basis	138,900,000	8,438,000	7,105,000	—1,333,000
Plan 4. Interest at 4 per cent and 50-year amortization on a 4 per cent sinking fund basis	137,400,000	8,179,000	7,105,000	—1,074,000
Plan 5. Interest at 3½ per cent and 50-year amortization on a 3½ per cent sinking fund basis	136,000,000	7,564,000	7,105,000	—459,000
Plan 6. Interest at 3 per cent and 50-year amortization on a 3 per cent sinking fund basis	134,500,000	6,975,000	7,105,000	+130,000
Plan 7. No interest and repayment of principal sum in 40 equal annual installments	125,400,000	4,767,000	7,105,000	+2,338,000
With Direct Federal and State Contributions—				
Plan 8. Same as Plan 1, with direct Federal contribution of $6,000,000 in the interest of navigation and State contribution of $3,400,000 for the relocation of State highway above Kennett Reservoir	*$129,500,000	$8,980,000	$7,105,000	—$1,875,000
Plan 9. Same as Plan 2, with Federal and State contributions as in Plan 8	*129,500,000	8,475,000	7,105,000	—1,370,000
Plan 10. Same as Plan 3, with Federal and State contributions as in Plan 8	*129,500,000	7,989,000	7,105,000	—884,000
Plan 11. Interest at 4½ per cent and refunding bonds, with same Federal and State contributions as in Plan 8	*129,500,000	7,512,000	7,105,000	—407,000
Plan 12. Same as Plan 5 with Federal and State contributions as in Plan 8	*126,600,000	7,188,000	7,105,000	—83,000
Plan 13. Same as Plan 12 with Federal contribution increased to $20,000,000	*112,600,000	6,591,000	7,105,000	+514,000

*Direct Federal and State contributions not included.
[1] Includes a revenue of $420,000 for sale of stored water in the Sacramento Valley and Sacramento-San Joaquin Delta, not shown in Table 168.

Complete Initial Development of State Water Plan in San Joaquin River Basin

The complete initial development of the State Water Plan in the San Joaquin River Basin differs from the immediate initial plan of development in that a much larger supply of water would be furnished to provide with greater certainty for the complete relief of the present developed areas in the upper San Joaquin Valley, for more substantial ground water replenishment and for expansion of irrigated areas on lands adjacent to present developments in accord with reasonable anticipations of growth in the immediate future. Under the proposed plan for immediate initial development as previously presented, it has been shown that the utilization of the grass land and surplus waters of the San Joaquin River through regulation in Friant Reservoir would provide supplemental water supplies which, in combination with local supplies, would meet the full requirements of present developed areas and replenish the underground reservoirs in the upper San Joaquin Valley, based upon a detailed study of operation during the subnormal period of run-off 1917–1929. However, it can not be certain in future years that there will not be seasons or periods of run-off even more subnormal than during the period 1921–1929 on which the water supply studies were based and it may be found that additional supplemental water supplies would be required to provide adequate and dependable relief to the present developed areas of deficient water supply in the upper San Joaquin Valley. Moreover it appears reasonable to anticipate that economic conditions in the future would justify an expansion of irrigated agriculture in the San Joaquin Valley, necessitating additional water supplies from outside sources.

The only dependable and practicable source of such additional supplemental supplies would be the Sacramento River Basin. Therefore, when water supplies in addition to the amounts which could be made available from the proposed plan of immediate initial development are required in the upper San Joaquin Valley, either for the purpose of more adequately meeting the needs of present developed areas for actual net use requirements and ground water replenishment, or for expansion of irrigated areas, or for both purposes, importation of Sacramento River Basin water will be required. It is considered that this would be a second step in the initial development and, as previously stated, it is believed that the construction of units to provide for importation of Sacramento River Basin water to the San Joaquin Valley could be deferred. However, in view of the possible need for additional supplemental water supplies from this source to adequately meet the full requirements in a plan of initial development, provision should be made in any plan of financing for the initial development for funds to cover the cost of the physical works required for importation of Sacramento River Basin water to the upper San Joaquin Valley.

Alternate Plans Investigated—In the formulation of a plan for the importation of water from the Sacramento River Basin to the upper San Joaquin Valley, several alternate plans were investigated. Of these, four have been selected for presentation in the following discussion, with comparisons of capital and annual costs. Two of the plans would not fit in with the proposed plan of immediate initial development as previously set forth and therefore would not be in the nature of a second step in the initial development but rather independent plans for initial development in one step.

Among the plans investigated for the conveyance of water from the Sacramento River Basin to the upper San Joaquin Valley was one with a concrete lined gravity canal extending from the Middle Fork of the Feather River to the Kern River. A field reconnaissance and cost estimate were made for such a canal with a maximum capacity of 3000 second-feet on this location. The route was located on U. S. Geological Survey topographic maps. Grades of .0001 foot per foot were used for canals, .0008 for tunnels and .001 for high head siphons. Allowances were made for suitable losses of head for minor structures. The diversion elevation at the Middle Fork of the Feather River would be 852 feet; at South Fork of Feather River, 835 feet; at Yuba River, 790 feet; at North Fork of American River, 743 feet; and at South Fork of American River, 735 feet. The water surface elevation at the San Joaquin River siphon would be 475 feet. The location from the San Joaquin River to Kern River would be the same as the San Joaquin River-Kern County Canal of the adopted State Plan. The diversion intakes of this conduit on the Sacramento River tributaries would be above the proposed locations of most of the major reservoirs of the State Water Plan and hence the canal could not obtain regulated supplies therefrom. It would also be above watershed areas from which originates a large part of the potential surplus water of the Sacramento River Basin. It would be necessary to develop storage above the canal to provide the supplies required for importation during several months of most years. The conduit would tortuously follow a grade contour on steep mountain hillsides, wind in and out around rocky spurs and into receding ravines, pass under granite peaks and ridges in tunnels and cross innumerable drainage channels in high head siphons. The total length would be about 558 miles.

A second plan investigated, which would involve an exchange of water supplies on the upper San Joaquin River, was a gravity conduit with a capacity of 3000 second-feet extending from the Folsom Reservoir on the American River to Mendota on the San Joaquin River, where canals which now serve large irrigated areas in the lower San Joaquin Valley, head. The diversion elevation of 345 feet at the Folsom dam site would require about 150,000 acre-feet of dead storage in Folsom Reservoir. This conduit would include ten miles of tunnels, nine miles of major tributary river crossing pressure siphons and more than 150 miles of canal located in pervious and rocky hillside formation, necessitating a concrete lined section. Its total length would be 215 miles. The plan would also include all units of the immediate initial development in the upper San Joaquin Valley. It would involve the construction of Folsom Reservoir and hence some modification of the initial plan of development in the Sacramento River Basin.

A scheme, differing from but similar in some respects to the first and second plans considered, was investigated, which would provide for exchange of supplies by means of canals from one stream to another on the east side of the valley from the Feather River to the Kern River. This scheme would involve water right adjustments on each stream and would be more costly than the second plan investigated because of the additional diversion and regulatory storage works required on each stream and the more unfavorable topographic conditions for locating the various exchange conduits above present irrigation development. The quantity of water which could be imported by such an exchange system would be limited by the flow of the stream having the smallest yield. Because of its obvious infeasibility, no cost estimates are presented for this scheme.

A third plan studied was a direct pumping system from the delta channels of the Sacramento and San Joaquin rivers to the upper San Joaquin Valley, with only a partial exchange of supplies on San Joaquin River. The San Joaquin River Pumping System, as set forth in detail in the adopted plan subsequently presented, would convey water to Mendota. From this point a pumping system and conduit would be extended southward to the vicinity of Bakersfield thereby utilizing imported water on the lower valley floor lands and releasing local supplies now used on such lands for use on higher areas. The San Joaquin River grass land and surplus waters would be regulated in Friant Reservoir to serve the Madera and Kings River areas. All other demands on the lower valley floor lands of the upper San Joaquin Valley would be satisfied by imported water. Including the utilization of Fresno Slough for the first twelve miles, the conveyance channel and pumping system from Mendota would extend southeasterly for 41 miles to a point about three miles north of Riverdale and thence easterly a distance of 19 miles, crossing the Kings River just above its point of bifurcation about 2 miles south of Kingsburg at elevation 293 feet. In this first 60 miles there would be six lifts of 27 feet each. It would then traverse a southeasterly direction for an additional 19 miles, crossing the St. John's branch of the Kaweah River two and one-half miles northeast of Visalia at elevation 362 feet. There would be three lifts of 27 feet each on the latter ten miles of this reach of the canal along the St. John's River. From the St. John's River the canal would extend southeasterly 10 miles to a point about midway between Exeter and Lindsay and thence somewhat west of south for an additional 10 miles to a crossing on the Tule River at elevation 348 feet from which point it would follow the Tule River southeasterly a distance of 4 miles to a point about 5 miles west of Porterville at elevation 402 feet. There would be two lifts of 27 feet each on the 5-mile reach of canal along the Tule River. From Tule River south to the terminus at Kern River the location would be identical with that of the proposed San Joaquin River-Kern County Canal. The total lift would be 297 feet and the total length of the canal from Mendota to Kern River 161 miles. It would have a capacity of 2000 second-feet to Poso Creek and 1500 second-feet from Poso Creek to Kern River. Other items included in this plan would be:

1. The Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System, in accord with the plan subsequently set forth.
2. A reservoir at Friant with a gross capacity of 200,000 acre-feet and a net capacity of 150,000 acre-feet above elevation 420 feet.
3. The Madera Canal with a capacity of 1500 second-feet as proposed in the State Plan.
4. A canal from Friant reservoir to Kings River about 30 miles in length having a diversion elevation of 420 feet, a terminus about 2 miles southeast of Sanger at elevation 325 feet and a capacity of 1000 second-feet.

The fourth plan investigated and finally selected for adoption provides for the diversion of the supplemental water supply from the Sacramento River Basin by pumping from the Sacramento-San Joaquin Delta. The physical units of the plan would comprise the Sacramento-San Joaquin Delta Cross Channel as described in detail in Chapter VI, the San Joaquin River Pumping System with a maximum capacity of 3000 second-feet, and all of the units of the proposed immediate initial development. Sacramento River water pumped from the delta, together with return flow and surplus waters of the lower San Joaquin Valley intercepted by the pumping system, would be substituted for San Joaquin River water now used on crop lands in the lower San Joaquin Valley above the mouth of Merced River. By means of this exchange, practically the entire flow of the San Joaquin River would be regulated in Friant Reservoir and would be made available for diversion to and utilization in the upper San Joaquin Valley.

Alternate Plans for San Joaquin River Pumping System—Many different plans and routes were considered for a pumping system to convey water from the delta to Mendota. These varied in range from that of a plan to attain the total elevation required by a series of pumping lifts located on the shortest line possible from a point near Paradise Dam westerly toward the foothills and thence continuing southerly through a constructed gravity canal along the west slope of the valley to Mendota, to a plan with a series of dams and pumping lifts utilizing the channel of the San Joaquin River throughout its entire length from the delta to Mendota. In all of the alternate plans of the San Joaquin River Pumping System studied, the same three main channels would be utilized for the conveyance of water from the terminus of the Sacramento-San Joaquin Delta Cross Channel at Central Landing to the first pumping plant. The most easterly of these channels would be the Stockton Deep Water Channel and the San Joaquin River. The other two main channels would be Old River and Salmon Slough, and Middle River with artificial connections already constructed such as the Victoria-North Canal and the Grant Line Canal. With some enlargement in portions of these channels, the conveyance capacity would be adequate to meet the requirements for exportation of water to the San Joaquin Valley and also for delta irrigation use. Descriptions of seven of the alternate plans studied follow herewith.

Plan No. 1, following a route designated as "West Side High Line," would consist of a dredged cut about two miles long from the river channel at Paradise Dam to the first pumping plant, then eight successive lifts of 27 feet each, connected by concrete lined canals, with a total length of about seven miles to the foothills on the west side of the valley. From this point the canal location would skirt the foothills for about 100 miles, terminating at Mendota at elevation 159. This location traversing the coarser and more pervious soils would necessitate the construction of a concrete lined canal as all water would be lifted 216 feet at the intake of the system and canal losses could not be recovered economically for utilization.

Plan No. 2, following a route designated as the "All River Channel" location, would consist of 14 mechanically operated steel leaf dams in the river channel between the delta and Mendota with a pumping plant at each dam, and a branch channel extending into Salt Slough above Dam No. 6 with three lifts delivering a portion of the pumped supply into the present main canal system near Los Banos. The remaining quantity would be pumped through the other eight river lifts to elevation 159, immediately above the present Mendota Weir. The river channel is exceedingly variable, both in grade and cross-section. Therefore, it would be necessary to space the dams at irregular intervals and design each pumping plant for its particular lift. The heights of lift would vary from 11 to 18 feet. From the mouth of the Merced River northerly, the water surface above each proposed dam would be maintained as nearly as possible at ground level to afford a minimum obstruction to the spreading of flood flows. Upstream from the Merced River, levees would be provided of sufficient height and distance apart to confine flood flows as regulated by the proposed Friant reservoir. The heights of lift in this section would be such that the water surface elevation above each dam would be abou that of the maximum flood plane level. This limits the elevation of the surface of pumped water to about seven feet above the general ground elevation immediately above the dams. Provision would be made for widening, straightening and deepening the river channel, where necessary, below dams, to give the required conveyance capacity without excessive head losses. Movable knockdown wing dams about 8 feet high would be provided across the overflow channels. These wing dams would connect the mechanically operated steel leaf dams in the river channel with the flood control levees. Levees would be constructed partly from outside borrow pits which would be utilized to collect and convey irrigation drainage water to the pool below each dam. These levees would traverse both banks of the large tributary drainage channels to the required flood control elevation. The pumping plants would be so designed and located that they would be fully protected from damage even with extreme floods.

Plan No. 3, following a route designated as the "West Side Valley Trough" location, would consist of 98 miles of unlined canal through the west side trough of the valley and eight pumping plants with uniform lifts of 26 feet each making delivery to Mendota, and one pumping plant having a lift of 23 feet discharging into the present main west side canal system near Los Banos. The canal would traverse largely an impervious soil of poor quality for agricultural use but underlaid and intercepted by flowing sand "kidneys" of considerable volume and extent. A return flow pick-up channel from the river would intercept the canal below each main pumping lift, so that seepage losses would be largely recoverable below each plant as in the "All River Channel" route. Spillway structures and channels to the river would be provided between lifts at suitable elevations. This plan would have uniform lifts and pumping units throughout, and would leave the river channel unaltered except at a few extreme westerly bends where topography makes economical its utilization as part of the conveyance channel and the substitution of new flood channels therefor. An examination of the logs of a number of wells throughout the valley trough between Newman and Mendota showed that flowing sand was encountered at depths of from six to eight feet from the surface along this route. Consideration of the difficulties which would be encountered in the construction of this system with lifts of 26 feet, requiring heavy cuts in flowing sand which might prevent excavation to the required depths and make canal maintenance at reasonable cost impossible, led to the tentative abandonment of this plan. Intensive exploration, including the procuring of soil samples to greater depths at close intervals, might result in discovering a route that would make this plan feasible.

Plan No. 4 would include the first five dams and pumping lifts of Plan No. 2, utilizing the river channel from the delta to the Merced River. Leaving the river at this point the system would consist of five 26.5 foot lifts connected by unlined canals running some 61 miles through the valley trough on the east side of the river southerly to Mendota. These canals would be located west of all "Class 1 and 2 lands" on the east side of the river and nearly the full capacity would be lifted to Mendota for distribution on the west side of the valley.

Plan No. 5 would include the first five dams and pumping lifts of Plan No. 2, utilizing the river channel to Fremont Ford, seven miles above Merced River, from which point an unlined canal would convey the water from the river to Pumping Plant No. 6, where it would be lifted 26.5 feet. Above Plant No. 6 a system of successive lengths of unlined canal following the same route as Plan No. 3 and utilizing west side slough channels wherever possible, with uniform pumping lifts of 26.5 feet, would convey part of the water into the present west side canal system near Los Banos and the remaining supply to Mendota. This plan was tentatively abandoned for the same reason as Plan No. 3.

Plan No. 6 would be a high line location similar to Plan No. 1, with the exception that there would be provided two sets of lifts, the first extending westerly from a point near Paradise dam and the second near Los Banos. A portion of the pumped supply would be delivered into the present canal system near Los Banos before pumping through the second set of lifts.

Plan No. 7 would include the first five dams and pumping lifts of Plan No. 2, utilizing the channel of the San Joaquin River from the first pumping plant, located just above the point of bifurcation of the San Joaquin and Old River, to the mouth of Merced River, a distance of 72 miles. By means of a series of five successive dams and pumping plants, water would be conveyed from the delta and raised to an elevation of 62 feet U. S. Geological Survey datum. The dams used for this portion of the conveyance system would be of the collapsible type so that the river channel could be opened to permit free discharge in case of large flows. From the pond above Plant No. 5 i is proposed to depart from the river with a constructed canal extending southerly along the most favorable topography. By means o three pumping lifts in a distance of seven miles the water would b raised to an elevation of 137 feet at the discharge of Plant No. 8 an would continue a distance of sixteen miles to Plants Nos. 9 and 10 about five miles west of Los Banos. An exchange would be mad with existing systems serving lands lying below Plant No. 9. Fro the discharge of Plant No. 10, at an elevation of 180 feet, the cana would extend southerly about 38 miles to the Mendota Weir, deliver ing water at an elevation of 159 feet. The pond above the Mendot Weir would be the source of supply for lands now served by diversion at and near this point. The design and layout of Plan No. 7, excep for canal and pumping capacity, are identical with the plan of th San Joaquin River Pumping System for ultimate development as s forth in Chapter VI. Estimates of cost are presented on two base first, with a concrete lined canal throughout and, secondly, with concrete lined canal from the river to Los Banos Creek and unline canal for the last 36 miles located in relatively impervious soils fro Los Banos Creek to Mendota.

Cost of Alternate Plans for Complete Initial Development—Esti mates of capital and annual cost of the four alternate plans investigat for complete initial development, including detailed estimates for ea of the major conveyance units of each plan and of each of the alterna plans considered for the San Joaquin River Pumping System, are s forth in Tables 170 to 182, inclusive. The estimates of the respecti units are strictly comparable both as to type of construction and unit prices used. All estimates are based on the same types of construction as described in Chapter VI for the units of the ultimate State Water Plan. Unit prices for Friant dam are the same as set forth in Table 66, those of the pumping systems the same as in Table 105 and those for canals the same as in Table 108. The unit prices of construction, set forth in the tables in Chapter VI above referred to, are for the items in place and are exclusive of amounts for administration, engineering, contingencies and interest during construction. To each cost estimate there has been added 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction at 4.5 per cent, computed on a basis of financing at the beginning of each six months and compounded to the end of the construction period. Estimates of annual costs including those for interest and amortization on bonds, depreciation, operation and maintenance are presented for each unit. Annual electric energy costs are estimated for conveyance units having pumping plants. The bases for estimating annual costs are the same as set forth in Chapter VI for storage and conveyance units of the ultimate State Plan.

TABLE 170

COST OF GRAVITY CANAL FEATHER RIVER TO KERN RIVER

Feather River to American River		
Section length, 118 miles. Capacity, 3,000 second-feet.		
Diversion dams	$900,000	
Tunnels	10,530,000	
Siphons	4,941,000	
Canal	18,657,000	
Minor structures	410,000	
Right of ways and fencing	160,000	
		$35,598,000
American River to San Joaquin River		
Section length, 284 miles. Capacity, 3,000 second-feet.		
Tunnels	$18,810,000	
Siphons	6,964,000	
Canal	43,361,000	
Minor structures	1,120,000	
Right of ways and fencing	350,000	
		70,605,000
San Joaquin River to Tule River		
Section length, 98 miles. Capacity, 3,000 second-feet.		
Tunnels	$392,000	
Siphons	1,064,000	
Canal	11,021,000	
Minor structures	1,270,000	
Right of ways and fencing	1,122,000	
		14,869,000
Tule River to Deer Creek		
Section length, 7 miles. Capacity, 2,500 second-feet.		
Siphons	$70,000	
Canal	539,000	
Minor structures	74,000	
Right of ways and fencing	33,000	
		716,000
Deer Creek to Poso Creek		
Section length, 27 miles. Capacity, 2,000 second-feet.		
Siphons	$75,000	
Canal	1,892,000	
Minor structures	329,000	
Right of ways and fencing	147,000	
		2,443,000
Poso Creek to Kern River		
Section length, 24 miles. Capacity, 1,500 second-feet.		
Canal	$1,445,000	
Minor structures	160,000	
Right of ways and fencing	99,000	
		1,704,000
Subtotal		$125,935,000
Administration and engineering, at 10 per cent		12,593,000
Contingencies, at 15 per cent		18,890,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		25,030,000
Total capital cost		$182,448,000
Total annual cost		$14,778,000

TABLE 171

COST OF GRAVITY CANAL AMERICAN RIVER TO MENDOTA

Length, 215 miles. Capacity, 3,000 second-feet.

Tunnels	$11,770,000	
Siphons	7,230,000	
Canal	20,418,000	
Minor structures	1,600,000	
Right of ways and fencing	522,000	
Subtotal		$41,540,000
Administration and engineering, at 10 per cent		4,154,000
Contingencies, at 15 per cent		6.231,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		5,546,000
Total capital cost		$57,471,000
Total annual cost		$4,581,000

ADDITIONAL STORAGE CAPACITY REQUIRED AT FOLSOM RESERVOIR

Assuming the Folsom reservoir included in the plan of initial development, its height would be increased 20 feet to compensate for the loss of effective storage below the diversion elevation of the American River-Mendota Canal. The height of dam would be increased from 190 to 210 feet, the gross storage capacity from 355,000 to 500,000 acre-feet and the high water surface from elevation 390 to 410 feet.

Capital cost of additional storage	$3,365,000
Annual cost of additional storage	$202,000
Total costs—	
Capital cost	$60,836,000
Annual cost	$4,783,000

TABLE 172

COST OF MENDOTA-BAKERSFIELD PUMPING SYSTEM

Fresno Slough to Tule River

Length, 91.8 miles. Capacity, 2,000 second-feet.

Excavation and embankment:		
Unlined cut from Fresno Slough to first lift, 1,050,000 cubic yards at $0.15	$158,000	
For concrete lined canal in deep cut and fill sections near pumping plants, 10,560,000 cubic yards at $0.20 to $0.23	2,270,000	
For regular concrete lined canal, earth, 1,603,000 cubic yards at $0.18	289.000	
Concrete lining, reinforced, 36,060,000 square feet at $0.15	5,409,000	
Pumping plants, with a capacity of 2,000 second-feet and a lift of 27 feet each, 11 at $272,000	2,992,000	
Minor structures:		
Intake control	20,000	
Kings River siphon	127,000	
St. Johns River siphon	35,000	
Cottonwood Creek siphon	46,000	
Tule River siphon	46,000	
Railroad crossings, 5 at $20,000	100,000	
Highway crossings, 12 at $9,500	114,000	
County road crossings, 45 at $6,000	270,000	
Secondary road crossings, 30 at $3,300	99,000	
Underdrains, 45 at $1,300	59,000	
Checks and outlets, 3 at $10,700	32,000	
Spillway structures, 11 at $10,000	110,000	
Right of ways and fencing	450,000	
		$12,626,000

Tule River to Poso Creek

Length, 33.8 miles. Capacity, 2,000 second-feet.

Excavation:		
For regular concrete lined canal: earth, 1,950,000 cubic yards at $0.18	$351,000	
Concrete canal lining, reinforced, 13,757,000 square feet at $0.15	2,064,000	
Minor structures:		
Deer Creek siphon	57,000	
White River siphon	25,000	
Rag Gulch siphon	25,000	
Poso Creek siphon	25,000	
Railroad crossing	20,000	
Highway crossings, 2 at $9,500	19,000	
County road crossings, 31 at $6,000	186,000	
Secondary road crossings, 15 at $3,300	50,000	
Underdrains, 38 at $3,000	114,000	
Checks and outlets, 2 at $10,700	21,000	
Right of ways and fencing	180,000	
		3,137,000

TABLE No. 172—Continued

Poso Creek to Kern River

Length, 23.8 miles. Capacity, 1,500 second-feet.

Excavation:		
For regular concrete lined canal, earth, 1,061,000 cubic yards at $0.18	$191,000	
Concrete canal lining, reinforced, 8,358,000 square feet at $0.15	1,254,000	
Minor structures:		
Railroad crossing	17,000	
Highway crossing	9,000	
County road crossings, 5 at $4,500	23,000	
Secondary road crossings, 15 at $3,000	45,000	
Underdrains, 68 at $900	61,000	
Check and outlets	8,000	
Right of ways and fencing	99,000	
		$1,707,000
Subtotal		$17,470,000
Administration and engineering, at 10 per cent		1,747,000
Contingencies, at 15 per cent		2,620,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		2,332,000
Total capital cost		$24,169,000
Annual cost, exclusive of energy		$2,059,000
Average annual energy charge, 308,887,000 kilowatt-hours at $0.0055		1,699,000
Total annual cost		$3,758,000

TABLE 173

COST OF CANAL FROM FRIANT RESERVOIR TO SERVE KINGS RIVER AREA, ONLY

Diversion elevation, 420 feet. Capacity, 1,000 second-feet. Length, 30 miles.

First 9 Miles in Foothills		
Excavation:		
Rock, 80,000 cubic yards at $1.00	$80,000	
Earth overlying rock, 100,000 cubic yards at $0.25	25,000	
Hardpan 310,000 cubic yards at $0.60	186,000	
Earth, 180,000 cubic yards at $0.18	32,000	
Rock trimming, 300,000 square feet at $0.10	30,000	
Concrete lining: 2,025,000 square feet at $0.16	324,000	
Structures:		
Little Dry Creek siphon	100,000	
Minor siphons, 3 at $10,000	30,000	
Highway crossing	6,000	
Road crossings, 6 at $3,500	21,000	
Railroad crossing	12,000	
Underdrains, 3 at $2,000	6,000	
Right of ways and fencing	20,000	
		$872,000
From Edge of Foothills to Centerville Bottoms Length 18 Miles		
Excavation: Earth, 870,000 cubic yards at $0.18	$157,000	
Concrete lining: 5,300,000 square feet at $0.15	795,000	
Structures:		
Dry Creek siphon	10,000	
Railroad crossings, 3 at $12,000	36.000	
Highway crossings, 3 at $6,000	18,000	
Road crossings, 30 at $3,500	105,000	
Underdrains, 5 at $2,000	10,000	
Main canal crossings, 2 at 6,000	12,000	
Minor canal crossings, 20 at $3,000	60,000	
Control and turnout structures, 8 at $4,000	32,000	
Drop into Centerville Bottoms	12,000	
Right of ways and fencing	300,000	
		1,547,000
Enlargement of Natural Channels in Centerville Bottoms Length 3 Miles		
Excavation: Earth, 150,000 cubic yards at $0.15	$23,000	
Right of ways and fencing	10,000	
		33,000
Subtotal		$2,452,000
Administration and engineering, at 10 per cent		245,000
Contingencies, at 15 per cent		368,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		213,000
Total capital cost		$3,278,000
Total annual cost		$261,000

TABLE 174

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 1, WEST SIDE HIGH LINE ROUTE

Central Landing to Paradise Dam		
Length 36 miles.		
Excavation and embankment:		
Enlargement of delta channels 4,800,000 cubic yards at $0.10	$480,000	
Right of ways:		
For channel enlargement and spoil areas	120,000	
		$600,000
Paradise Dam to Los Banos Creek		
Length, 60 miles. Capacity, 3,000 second-feet.		
Excavation:		
Unlined cut from Paradise dam to first lift, 1,100,000 cubic yards at $0.15	$165,000	
For concrete lined canal in deep cut and fill sections near pumping plants, 1,125,000 cubic yards at $0.20 to $0.23	240,000	
For regular concrete lined canal; earth, 4,560,000 cubic yards at $0.18	821,000	
Hardpan, 460,000 cubic yards at $0.60	276,000	
Concrete lining, reinforced: 29,560,000 square feet at $0.15	4,434,000	
Pumping plants: With a capacity of 3,000 second-feet and a lift of 27 feet each, 8 at $408,000	3,264,000	
Siphon: Diameter 23 feet, length 5,500 feet	850,000	
Minor structures:		
River intake control	25,000	
Railroad crossing	25,000	
Underdrains, 27 at $2,000	54,000	
Road crossings, 22 at $7,000	154,000	
Minor siphons, 3 at $10,000	30,000	
Right of ways and fencing	210,000	
		10,548,000
Los Banos Creek to Mendota		
Length, 39 miles. Capacity, 2,000 second-feet.		
Excavation:		
For regular concrete lined canal: Earth, 2,400,000 cubic yards at $0.18	$432,000	
Hardpan, 40,000 cubic yards at $0.60	24,000	
Concrete canal lining, reinforced: 14,839,000 square feet at $0.15	2,226,000	
Minor structures:		
Railroad crossing	20,000	
Underdrains, 5 at $1,600	8,000	
Road crossings, 18 at $6,000	108,000	
Minor siphon	9,000	
Right of ways and fencing	90,000	
		2,917,000
Subtotal		$14,065,000
Administration and engineering, at 10 per cent		1,406,000
Contingencies, at 15 per cent		2,110,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,878,000
Total capital cost		$19,459,000
Annual cost, exclusive of energy		$1,680,000
Average annual energy charge, 332,000,000 kilowatt hours at $0.0055		1,826,000
Total annual cost		$3,506,000

TABLE 175

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 2, ALL RIVER CHANNEL ROUTE

Central Landing to Merced River	
Length, 102 miles. Capacity varies from 2,000 to 2,500 second-feet.	
Excavation and embankment:	
Enlargement of delta channels below Dam No. 1, 4,000,000 cubic yards at $0.10	$400,000
Channel changes and enlargement between dams, 1,685,000 cubic yards at $0.10	168,000
Levee embankment above dams, 518,000 cubic yards at $0.15	78,000
Pumping plants:	
Lift No. 1, capacity, 2,000 second-feet; height of lift, 18 feet	235,000
Lift No. 2, capacity, 2,000 second-feet; height of lift, 13 feet	213,000
Lift No. 3, capacity, 2,500 second-feet; height of lift, 13 feet	266,000
Lift No. 4, capacity, 2,500 second-feet; height of lift, 13 feet	265,000
Lift No. 5, capacity, 2,500 second-feet; height of lift, 13 feet	265,000
Steel leaf dams:	
Dam No. 1	172,000
Dam No. 2	172,000
Dam No. 3	123,000
Dam No. 4	208,000
Dam No. 5	147,000

TABLE 175—Continued

Minor structures:				
Drainage culverts through levees			$20,000	
Control works at Paradise Dam			25,000	
Maintaining existing bridges during construction			50,000	
Right of ways:				
Delta channel enlargement and spoil areas			100,000	
River levees and spoil areas			90,000	
				$2,997,000
Merced River to Mendota				
Length, 88 miles. Capacity varies from 3,000 to 2,000 second-feet.				
Excavation and embankment:				
Channel changes and enlargement between dams, 6,415,000 cubic yards at $0.10			$642,000	
Changes in existing canal locations, 400,000 cubic yards at $0.15			60,000	
Levees along main river, 8,682,000 cubic yards at $0.15			1,302,000	
Levees along Mariposa Slough, Bear River, Fresno River, Ash Creek and Berenda Slough, 2,800,000 cubic yards at $0.15			420,000	
Pumping plants:				
Lift No. 6, capacity, 3,000 second-feet; height of lift, 13 feet			319,000	
Lift No. 7, capacity, 2,000 second-feet; height of lift, 13 feet			213,000	
Lift No. 8, capacity, 2,000 second-feet; height of lift, 11 feet			204,000	
Lift No. 9, capacity, 2,000 second-feet; height of lift, 11 feet			204,000	
Lift No. 10, capacity, 2,000 second-feet; height of lift, 11 feet			204,000	
Lift No. 11, capacity, 2,000 second-feet; height of lift, 13 feet			213,000	
Lift No. 12, capacity, 2,000 second-feet; height of lift, 13 feet			213,000	
Lift No. 13, capacity, 2,000 second-feet; height of lift, 13 feet			213,000	
Lift No. 14, capacity, 2,000 second-feet; height of lift, 11 feet			204,000	
Steel leaf dams:	Cost of main dams	Cost of A-frame dams between main dams and flood control levees		
Dam No. 6	$123,000	$84,000	$207,000	
Dam No. 7	98,000	87,000	185,000	
Dam No. 8	98,000	87,000	185,000	
Dam No. 9	98,000	87,000	185,000	
Dam No. 10	123,000	85,000	208,000	
Dam No. 11	123,000	85,000	208,000	
Dam No. 12	233,000	73,000	306,000	
Dam No. 13	178,000	78,000	256,000	
Dam No. 14	233,000	73,000	306,000	
Minor structures:				
Drainage culverts through levees			80,000	
Maintaining existing bridges during construction			50,000	
Right of ways			750,000	
				7,337,000
Salt Slough and Salt Slough Extension to Los Banos				
Length, 21 miles. Capacity, 1,000 second-feet.				
Excavation and embankment:				
Channel excavation in Salt Slough, 800,000 cubic yards at $0.10			$80,000	
Levees on Salt Slough, 1,500,000 cubic yards at $0.15			225,000	
Extension canal, for concrete lined section, 510,000 cubic yards at $0.20 to $0.23			110,000	
Concrete lining, reinforced; 1,925,000 square feet at $0.15			289,000	
Pumping plants:				
Lift No. 6A, capacity, 1,000 second-feet; height of lift, 18 feet			118,000	
Lift No. 6B, capacity, 1,000 second-feet; height of lift, 16 feet			114,000	
Lift No. 6C, capacity, 1,000 second-feet; height of lift, 16 feet			114,000	
Minor structures:				
Siphon under railroad and highway			25,000	
Road crossings, 5 at $7,000 and 5 at $3,000			50,000	
Right of ways			55,000	
				1,180,000
Subtotal				$11,514,000
Administration and engineering, at 10 per cent				$1,152,000
Contingencies, at 15 per cent				1,727,000
Interest during construction, based on an interest rate of 4.5 per cent per annum				1,537,000
Total capital cost				$15,930,000
Annual cost, exclusive of energy				$1,445,000
Average annual energy charges, 175,132,000 kilowatt-hours at $0.0055				963,000
Total annual cost				$2,408,000

TABLE 176

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 3, WEST SIDE VALLEY TROUGH ROUTE

Central Landing to Paradise Dam		
Length, 36 miles.		
Excavation and embankment:		
Enlargement of delta channels: 4,800,000 cubic yards at $0.10	$480,000	
Right of ways: Channel enlargement and spoil areas	120,000	
		$600,000
Paradise Dam to Los Banos Branch Canal		
Length, 58 miles. Capacity, 3,000 second-feet.		
Excavation and embankment:		
Main canal, unlined, 11,250,000 cubic yards at $0.15	$1,688,000	
Spillway and return flow pick up channels and minor stream channel changes, 990,000 cubic yards at $0.15	148,000	
Pumping plants: 5 with a lift of 26 feet each, at $408,000	2,040,000	
Minor structures:		
River intake control	25,000	
Road crossings, 34 at $8,000	272,000	
Patterson canal crossing	10,000	
Puerto Creek siphon	30,000	
Orestimba Creek siphon	30,000	
Spillway structures, 4 at $15,000	60,000	
Return water intake structures, 4 at $25,000	100,000	
Underdrains, 11 at $3,000	33,000	
Drainage inlets, 5 at $5,000	25,000	
Right of ways and fencing	250,000	
		4,711,000
Los Banos Branch Canal		
Length, 3.6 miles. Capacity, 1,000 second-feet.		
Excavation and embankment:		
Canal, unlined, 440,000 cubic yards at $0.15	$66,000	
Pumping plant, lift, 23 feet	130,000	
Minor structures:		
Control at branch	5,000	
Railroad and highway crossing	25,000	
Road crossings, 3 at $5,000	15,000	
Structure at intersection with existing canal	5,000	
Right of ways and fencing	15,000	
		261,000
Los Banos to Mendota		
Length, 36 miles. Capacity, 2,000 second-feet.		
Excavation and embankment:		
Main canal, unlined 6,050,000 cubic yards at $0.15	$908,000	
Spillway channels and stream channel changes, 230,000 cubic yards at $0.15	34,000	
Pumping plants: 3 with a lift of 26 feet each at $272,000	816,000	
Minor structures:		
Road crossings, 10 at $6,500	65,000	
Poso Canal siphon	8,000	
Spillway structures, 3 at $10,000	30,000	
Drainage inlets, 6 at $3,000	18,000	
Outlets, 3 at $3,000	9,000	
River control	50,000	
Return water intake	25,000	
Right of ways and fencing	215,000	
		2,178,000
Subtotal		$7,750,000
Administration and engineering, at 10 per cent		$775,000
Contingencies, at 15 per cent		1,162,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,035,000
Total capital cost		$10,722,000
Annual cost exclusive of energy		$933,000
Average annual energy charge, 291,500,000 kilowatt-hours at $0.0055		1,603,000
Total annual cost		$2,536,000

TABLE 177

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 4, RIVER CHANNEL ROUTE TO MERCED RIVER UNLINED CANAL EAST SIDE OF VALLEY TROUGH, MERCED RIVER TO MENDOTA

Central Landing to Merced River

Length, 102 miles. Capacity varies from 2,000 to 2,500 second-feet.

Excavation and embankment:		
Enlargement of delta channels below Dam No. 1, 4,000,000 cubic yards at $0.10	$400,000	
Channel changes and enlargement between dams, 1,685,000 cubic yards at $0.10	168,000	
Levee embankments above dams, 518,000 cubic yards at $0.15	78,000	
Pumping plants:		
Lift No. 1, capacity, 2,000 second-feet; height of lift, 18 feet	235,000	
Lift No. 2, capacity, 2,000 second-feet; height of lift, 13 feet	213,000	
Lift No. 3, capacity, 2,500 second-feet; height of lift, 13 feet	266,000	
Lift No. 4, capacity, 2,500 second-feet; height of lift, 13 feet	265,000	
Lift No. 5, capacity, 2,500 second-feet; height of lift, 13 feet	265,000	
Steel leaf dams:		
Dam No. 1	172,000	
Dam No. 2	172,000	
Dam No. 3	123,000	
Dam No. 4	208,000	
Dam No. 5	147,000	
Minor structures:		
Drainage culverts through levees	20,000	
Control works at Paradise Dam	25,000	
Maintaining existing bridges during construction	50,000	
Right of ways:		
Delta channel enlargement and spoil areas	100,000	
River levees and spoil areas	90,000	
		$2,997,000

Merced River to Mendota

Length, 63 miles. Capacity, 3,000 second-feet.

Excavation and embankment:		
Dredging on Merced River, 1,050,000 cubic yards at $0.10	$105,000	
Main canal, unlined, 12,280,000 cubic yards at $0.15	1,842,000	
Spillway channels, 120,000 cubic yards at $0.15	18,000	
Pumping plants: 5 with a lift of 26.5 feet each at $408,000	2,040,000	
Minor structures:		
Intake control at Merced River	25,000	
Bear Creek siphon	30,000	
Mariposa Slough siphon	40,000	
Chowchilla River siphon	50,000	
Ash Slough siphon	40,000	
Berenda Slough siphon	25,000	
Fresno Slough siphon	120,000	
Road crossings, 26 at $8,000	168,000	
Spillway structures, 4 at $15,000	60,000	
Canal crossings, 3 at $10,000	30,000	
Intake from Fresno River	15,000	
Minor drainage inlets, 3 at $5,000	15,000	
Underdrains, 5 at $3,000	15,000	
Right of ways and fencing	225,000	
		4,863,000
Subtotal		$7,860,000
Administration and engineering, at 10 per cent		$786,000
Contingencies, at 15 per cent		1,179,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,049,000
Total capital cost		$10,874,000
Average annual cost, exclusive of energy		977,000
Average annual energy charge, 238,000,000 kilowatt-hours at $0.0055		1,309,000
Total annual cost		$2,286,000

TABLE 178

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 5, RIVER CHANNEL ROUTE TO FREEMONT FORD UNLINED CANAL WEST SIDE OF VALLEY TROUGH, FREEMONT FORD TO MENDOTA

Central Landing to Fremont Ford		
Length, 109 miles. Capacity varies from 2,000 to 2,500 second-feet.		
Excavation and embankment:		
Enlargement of delta channels below Dam No. 1, 4,000,000 cubic yards at $0.10	$400,000	
Channel changes and enlargements between Dam No. 1 and Freemont Ford, 2,890,000 cubic yards at $0.10	289,000	
Levee embankments above dams, 518,000 cubic yards at $0.15	78,000	
Pumping plants:		
Lift No. 1, capacity, 2,000 second-feet; height of lift, 18 feet	235,000	
Lift No. 2, capacity, 2,000 second-feet; height of lift, 13 feet	213,000	
Lift No. 3, capacity, 2,500 second-feet; height of lift, 13 feet	266,000	
Lift No. 4, capacity, 2,500 second-feet; height of lift, 13 feet	265,000	
Lift No. 5, capacity, 2,500 second-feet; height of lift, 13 feet	265,000	
Steel leaf dams:		
Dam No. 1	172,000	
Dam No. 2	172,000	
Dam No. 3	123,000	
Dam No. 4	208,000	
Dam No. 5	147,000	
Minor structures:		
Drainage culverts through levees	20,000	
Control works at Paradise Dam	25,000	
Maintaining existing bridges during construction	50,000	
Right of ways:		
Delta channel enlargement and spoil areas	100,000	
River levees and spoil areas	100,000	
		$3,128,000
Fremont Ford to Los Banos Branch Canal		
Length, 18.5 miles. Capacity, 3,000 second-feet.		
Excavation and embankment:		
Main canal, unlined 3,390,000 cubic yards at $0.15	$509,000	
Pumping plants: 2 with a lift of 26.5 feet each at $408,000	816,000	
Minor structures:		
Control works at Fremont Ford	25,000	
Road crossings, 10 at $8,000	80,000	
Return water pick up structure at Salt Slough	20,000	
Drainage inlets, 3 at $5,000	15,000	
Right of ways and fencing	70,000	
		1,535,000
Los Banos Branch Canal		
Length, 3.6 miles. Capacity, 1,000 second-feet.		
Excavation and embankment:		
Canal, unlined, 440,000 cubic yards at $0.15	$66,000	
Pumping plant, lift 23 feet	130,000	
Minor structures:		
Control at branch	5,000	
Railroad and highway crossing	25,000	
Road crossings, 3 at $5,000	15,000	
Structure at intersection with existing canal	5,000	
Right of ways and fencing	15,000	
		261,000
Los Banos to Mendota		
Length, 36 miles. Capacity, 2,000 second-feet.		
Excavation and embankment:		
Main canal, unlined, 6,050,000 cubic yards at $0.15	$908,000	
Spillway channels and stream channel changes, 230,000 cubic yards at $0.15	34,000	
Pumping plants: 3 with a lift of 26 feet each at $272,000	816,000	
Minor structures:		
Road crossings, 10 at $6,500	65,000	
Poso Canal siphon	8,000	
Spillway structures, 3 at $10,000	30,000	
Drainage inlets, 6 at $3,000	18,000	
Outlets, 3 at $3,000	9,000	
River control	50,000	
Return water intake	25,000	
Right of ways and fencing	215,000	
		2,178,000
Subtotal		$7,102,000
Administration and engineering, at 10 per cent		710,000
Contingencies, at 15 per cent		1,065,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		948,000
Total capital cost		$9,825,000
Annual cost, exclusive of energy		$884,000
Average annual energy charge, 208,750,000 kilowatt-hours at $0.0055		1,148,000
Total annual cost		$2,032,000

TABLE 179

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 6
MODIFIED WEST SIDE HIGH LINE ROUTE

Central Landing to Paradise Dam		
Length, 36 miles.		
Excavation and embankment:		
Enlargement of delta channels, 4,800,000 cubic yards at $0.10	$480,000	
Right of ways:		
Delta channel enlargement and spoil areas	120,000	
		$600,000
Paradise Dam to Los Banos		
Length, 60 miles. Capacity, 3,000 second-feet.		
Excavation and embankment:		
Unlined cut from Paradise Dam to first lift, 100,000 cubic yards at $0.15	$15,000	
Concrete lined canal in deep excavation and embankment sections near pumping plants, 1,600,000 cubic yards at $0.20 to $0.23	344,000	
Canals with regular concrete lined section:		
Earth, 4,300,000 cubic yards at $0.18	774,000	
Hardpan, 80,000 cubic yards at $0.60	48,000	
Concrete canal lining, reinforced: 26,670,000 square feet at $0.15	4,000,000	
Pumping plants: 6 with a lift of 26.5 feet each at $408,000	2,448,000	
Minor structures:		
River intake control	25,000	
Railroad crossing	25,000	
Underdrains, 20 at $2,000	40,000	
Road crossings, 47 at $7,000	329,000	
Minor siphons, 7 at $10,000	70,000	
Right of ways and fencing	237,000	
		8,355,000
Los Banos to Mendota		
Length, 40 miles. Capacity, 2,000 second-feet.		
Excavation:		
Concrete lined canal in deep excavation and embankment sections near pumping plants, 250,000 cubic yards at $0.20 to $0.23	$54,000	
Canals with regular concrete lined section:		
Earth, 2,400,000 cubic yards at $0.18	432,000	
Hardpan, 40,000 cubic yards at $0.60	24,000	
Concrete canal lining, reinforced: 15,280,000 square feet at $0.15	2,292,000	
Pumping plants: 2 with a lift of 26.5 feet each at $272,000	544,000	
Minor structures:		
Railroad crossing	20,000	
Underdrains, 5 at $1,600	8,000	
Road crossings, 18 at $6,000	108,000	
Minor siphon	9,000	
Right of ways and fencing	114,000	
		3,605,000
Subtotal		$12,560,000
Administration and engineering, at 10 per cent		$1,256,000
Contingencies, at 15 per cent		1,884,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,677,000
Total capital cost		$17,377,000
Annual cost, exclusive of energy		$1,506,000
Average annual energy charge, 299,000,000 kilowatt-hours at $0.0055		1,644,000
Total annual cost		$3,150,000

TABLE 180

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM PLAN No. 7
ADOPTED PLAN, WITH ALL CANALS CONCRETE LINED

Central Landing to Hills Ferry		
Length, 102 miles. Capacity varies from 2,000 to 2,500 second-feet.		
Excavation and embankment:		
Enlargement of delta channels below Dam No. 1, 4,000,000 cubic yards at $0.10	$400,000	
Channel changes and enlargement between dams, 1,685,000 cubic yards at $0.10	168,000	
Levee embankments above dams, 518,000 cubic yards at $0.15	78,000	
Pumping plants:		
Lift No. 1, capacity, 2,000 second-feet; height of lift, 18 feet	235,000	
Lift No. 2, capacity, 2,000 second-feet; height of lift, 13 feet	213,000	
Lift No. 3, capacity, 2,500 second-feet; height of lift, 13 feet	266,000	
Lift No. 4, capacity, 2,500 second-feet; height of lift, 13 feet	265,000	
Lift No. 5, capacity, 2,500 second-feet; height of lift, 13 feet	265,000	
Steel leaf dams:		
Dam No. 1	172,000	
Dam No. 2	172,000	
Dam No. 3	123,000	
Dam No. 4	208,000	
Dam No. 5	147,000	
Minor structures:		
Drainage culverts through levees	20,000	
Control works at Paradise Dam	25,000	
Maintaining existing bridges during construction	50,000	
Right of ways:		
Delta channel enlargement and spoil areas	100,000	
River levees and spoil areas	90,000	
		$2,997,000
Hills Ferry to Mendota		
Length, 63 miles. Capacity varies from 3,000 to 2,000 second-feet.		
Excavation:		
Canals in deep cut and fill sections near pumping plants, 1,895,000 cubic yards at $0.20 to $0.23	$424,000	
Canals with regular concrete lined section:		
Earth, 4,029,000 cubic yards at $0.18	725,000	
Hardpan, 111,000 cubic yards at $0.60	67,000	
Spillway channel near Los Banos, 170,000 cubic yards at $0.15	25,000	
Concrete canal lining, reinforced: 24,306,000 square feet at $0.15	3,646,000	
Pumping plants:		
Lift No. 6, capacity, 3,000 second-feet; height of lift, 26.5 feet	408,000	
Lift No. 7, capacity, 3,000 second-feet; height of lift, 26.5 feet	408,000	
Lift No. 8, capacity, 3,000 second-feet; height of lift, 26.5 feet	408,000	
Lift No. 9, capacity, 2,000 second-feet; height of lift, 26.5 feet	272,000	
Lift No. 10, capacity, 2,000 second-feet; height of lift, 26.5 feet	272,000	
Minor structures on portion of canal having a capacity of 3,000 second-feet:		
Intake gates in cut near Hills Ferry	25,000	
Siphons, 3 at $10,000	30,000	
Railroad crossing	25,000	
Road bridges, 20 at $7,000	140,000	
Spillway channel control	10,000	
Bridges on spillway channel, 3 at $4,000	12,000	
Outlets, 2 at $5,000	10,000	
Underdrains, 3 at $2,000	6,000	
Minor structures on portion of canal having a capacity of 2,000 second-feet:		
Road bridges, 18 at $6,000	108,000	
Siphon	9,000	
Railroad crossing	20,000	
Outlets, 2 at $5,000	10,000	
Underdrains, 5 at $1,600	8,000	
Right of ways and fencing	296,000	
		7,364,00
Subtotal		$10,361,00
Administration and engineering, at 10 per cent		$1,036,00
Contingencies, at 15 per cent		1,554,00
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,383,00
Total capital cost		*$14,334,00
Annual cost, exclusive of energy		$1,266,00
Average annual energy charge, 207,000,000 kilowatt-hours at $0.0055		1,139,00
Total annual cost		*$2,405,00

* Capital and annual costs of $15,000,000 and $2,500,000, respectively, have been adopted for the estimate of th San Joaquin River Pumping System in order to make provision in the plan of financing for the construction of any of th alternative plans that more intensive exploration and study may reveal to be the most feasible and advantageous for a purposes, including those of navigation and flood control. See Chapters IX and X.

MODIFIED ADOPTED PLAN, WITH UNLINED CANAL BETWEEN LOS BANOS CREEK AND MENDOTA

Items of capital cost same as above, except that cost of excavation would be increased by addition of 1,761,000 cubi yards at $0.18 or $317,000; cost of concrete lining would be decreased by elimination of 13,816,000 square feet at $0.1 or $2,073,000; and overhead costs would be decreased corresponding to the net reduction in cost of these items. Annu cost, exclusive of electric energy charges, would also be reduced correspondingly.

Total capital cost	$11,714,0
Total annual cost	$2,182,0

Table 181 sets forth a comparative summary of capital and annual costs of the alternate plans investigated for the San Joaquin River Pumping System.

TABLE 181

SUMMARY OF COSTS OF ALTERNATE PLANS FOR SAN JOAQUIN RIVER PUMPING SYSTEM

Plan	Capital cost	Annual cost
No. 1, West Side High Line; all concrete lined canal	$19,459,000	$3,506,000
No. 2, All River Channel Route	15,930,000	2,408,000
No. 3, West Side Valley Trough Route, all unlined canal	10,722,000	2,536,000
No. 4, River Channel to Merced River, unlined canal east side of valley trough, Merced River to Mendota	10,874,000	2,286,000
No. 5, River Channel to Fremont Ford, unlined canal west side of valley trough, Fremont Ford to Mendota	9,825,000	2,032,000
No. 6, Modified West Side High Line Route; all concrete lined canal	17,377,000	3,150,000
No. 7, Adopted Plan, River Channel to Merced River and Canal to Mendota:		
With entire canal concrete lined	14,334,000	2,405,000
With unlined canal from Los Banos Creek to Mendota	11,714,000	2,182,000

Of the plans considered with various alternate routes for the San Joaquin River Pumping System, Plans 3 and 5 were tentatively eliminated because of flowing sand conditions. Plans 1 and 6 are eliminated from consideration because of higher capital and annual costs. Of the remaining Plans 2, 4 and 7, Plan No. 7 with an unlined canal from Los Banos Creek to Mendota would be cheaper in annual cost than either Plans 2 and 4. Plan No. 4 would be somewhat cheaper in annual cost than Plan No. 7 with a concrete lined canal throughout. Although Plan No. 7 with an unlined canal from Los Banos Creek to Mendota appeared after careful study and comparison and in the light of present knowledge to present the greatest advantages from all viewpoints, it was concluded that this plan with provision for a concrete lined canal throughout should be adopted as a basis for estimating the cost of the San Joaquin River Pumping System in order to assure ample funds for the construction of this unit in accord with any final plan that more intensive exploration and study may reveal to be the most feasible and advantageous for all purposes. The capital and annual costs for the San Joaquin River Pumping System used in the subsequent cost analyses have been set up as $15,000,000 and $2,500,000, respectively.

Navigation could be restored on the San Joaquin River as far upstream as Salt Slough by the incorporation of locks in the dams of the tentatively adopted plan. If it should be desirable to extend navigation to Mendota it could be accomplished by the adoption of Plan No. 2, and the incorporation of locks in all of the dams.

In Table 182 there are presented comparative summaries of the capital and annual costs of the four alternate plans investigated for complete initial development. These estimates do not include any portion of the cost of storage units which would be required in the Sacramento River Basin to provide regulated supplies for importation to the San Joaquin Valley or any other costs involved in the plan for complete initial development in the Sacramento River Basin. In all the plans considered storage would be required and the cost would vary to some extent under the different plans. The net cost of storage on the Feather, Yuba and American rivers would be greater than on the

Sacramento River in Kennett Reservoir. If storage costs were included, the differences in net annual costs between the gravity canal plans and the pumping plans would be more than indicated.

TABLE 182

SUMMARY OF CAPITAL AND ANNUAL COSTS OF ALTERNATE PLANS FOR COMPLETE INITIAL DEVELOPMENT OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN PROVIDING FOR IMPORTATION OF SUPPLEMENTAL WATER SUPPLIES FROM SACRAMENTO RIVER BASIN TO UPPER SAN JOAQUIN VALLEY

Plan	Capital cost	Annual cost
Gravity Canal, Feather River to Kern River Without Exchange of Supplies on San Joaquin River		
Canal, capacity 3,000 second-feet	$182,448,000	$14,778,000
Water rights and general expense	1,000,000	56,000
Totals	$183,448,000	$14,834,000
Gravity Canal, American River to Mendota and Exchange of Supplies on San Joaquin River		
American River-Mendota Canal, capacity 3,000 second-feet	$60,836,000	$4,783,000
Friant Reservoir, gross capacity 400,000 acre-feet, net capacity above elevation 467 feet, 270,000 acre-feet	14,000,000	840,000
Madera Canal, capacity 1,500 second-feet	2,500,000	213,000
San Joaquin River-Kern County Canal, capacity 3,000 second-feet	27,300,000	2,225,000
Water rights and general expense	5,000,000	278,000
Totals	$109,636,000	$8,339,000
San Joaquin River and Mendota-Bakersfield Pumping Systems, with Only Partial Exchange of Supplies on San Joaquin River		
Sacramento-San Joaquin Delta Cross Channel, one-half cost	$2,000,000	$150,000
San Joaquin River Pumping System, capacity 3,000 second-feet	15,000,000	2,500,000
Mendota-Bakersfield Pumping System, capacity 2,000 second-feet	24,169,000	3,758,000
Friant Reservoir, gross capacity 200,000 acre-feet, net capacity above elevation 420 feet, 150,000 acre-feet	7,000,000	420,000
Madera Canal, capacity 1,500 second-feet	2,500,000	213,000
Friant-Kings River Canal, capacity 1,000 second-feet	3,278,000	261,000
Water rights and general expense	5,000,000	278,000
Totals	$58,947,000	$7,580,000
San Joaquin River Pumping System and Exchange of Supplies on San Joaquin River		
Sacramento-San Joaquin Delta Cross Channel, one-half cost	$2,000,000	$150,000
San Joaquin River Pumping System, capacity 3,000 second-feet	15,000,000	2,500,000
Friant Reservoir, gross capacity 400,000 acre-feet, net capacity above elevation 467 feet, 270,000 acre-feet	14,000,000	840,000
Madera Canal, capacity 1,500 second-feet	2,500,000	213,000
San Joaquin River-Kern County Canal, capacity 3,000 second-feet	27,300,000	2,225,000
Water rights and general expense	5,000,000	278,000
Totals	$65,800,000	$6,206,000

Selection of Plan for Complete Initial Development—The selection of the most desirable plan for complete initial development must be based not only upon a consideration of capital and annual costs of the various alternative plans of development considered but also upon legal aspects with respect to interference with water rights and the adaptability of each plan in a progressive development looking towards the consummation of the ultimate plan of development. The desirability of providing a plan of complete initial development which would fit in with the proposed plan of immediate initial development and be in the nature of a second progressive step must also be considered.

The first two of the alternative plans considered, with gravity canals from the Sacramento River Basin, would divert water above the owners of riparian water rights and appropriative water rights with large diversions in the Sacramento Valley. The difficulty and confusion which would arise in making adjustments for such interference, which would be satisfactory to the present riparian and appropriative water right owners, would be large. In the light of present knowledge of the operation of the riparian doctrine, it would appear infeasible to divert supplemental supplies above these riparian lands. With respect to the second plan providing for diversion from the American River, such diversion would take water which would be required for ultimate development not only in the Sacramento River Basin but also in hydrographic divisions 12 and 13 of the lower San Joaquin Valley. However, in addition to these undesirable features of the first and second plans considered, the capital and annual costs for both of these plans greatly exceed those of the third and fourth plans.

The choice as to the most desirable plan for complete initial development therefore rests between the all pumping plan, with a pumping system from the delta to the vicinity of Bakersfield, and the plan providing a pumping system from the delta only to Mendota. Both of these plans would divert water from the delta channels below all riparian and appropriative water users and hence would not interfere with these vested rights. The supplemental supplies diverted from the delta would be obtained from surplus waters remaining after all appropriative and riparian rights on both the Sacramento and San Joaquin rivers had been satisfied. The third plan would involve exchanges of water on the San Joaquin, Kings, Kaweah and Tule rivers while the fourth plan would involve exchange of water only on the San Joaquin River. The third plan would not be well adapted to the consummation of a plan of initial development in two progressive steps nor would it fit in as well as the fourth plan with the proposed plan of ultimate development. The third plan would involve greater costs than the fourth plan for both immediate initial and ultimate developments. As a final consideration, the cost analyses show that the annual cost of the third plan involving a pumping system from the delta to Bakersfield would be considerably in excess of the annual cost of the fourth plan.

Based upon the foregoing considerations, the fourth plan has been selected as the most desirable plan for adoption. Of all plans investigated, the selected plan is the one that would entail the least annual cost, would involve the least interference with vested rights, and would be best adapted to a progressive development as related to both the immediate initial and the ultimate plans for the San Joaquin River Basin. Even if an annuity were added to the annual cost of the selected plan which with interest at 4 per cent would create at the end of forty years a fund, the interest on which at 4 per cent would pay electric energy charges for pumping of water for all time, the selected plan would still be smaller in annual cost than any plan involving a gravity canal that has been suggested or investigated. The annual cost with such an annuity added thereto would be increased to a total of $6,505,000. However, considering that both amortization and depreciation are included in the annual costs and that funds would be available on this basis to completely amortize the project in 40 years and also to rebuild each unit when its useful life had expired, the comparison including the creation of a fund to pay for the cost of electric energy is not justifiable. It is mentioned merely to point out that, by the most severe standards of measurement, pumping for all time under the selected plan would be more economical than a plan providing a gravity diversion from the Sacramento River Basin.

Proposed Plan for Complete Initial Development

The proposed plan for complete initial development would comprise, in addition to the units for proposed immediate initial development, the San Joaquin River Pumping System and the Sacramento-San Joaquin Delta Cross-Channel. All of these units have been previously described. Their locations are shown on Plate XXVI and other features of design are further delineated on Plate LXIX. In addition to these units, the initial storage unit (Kennett Reservoir) in the Sacramento River Basin is considered to be a part of the plan for the San Joaquin River Basin because it will be required to furnish regulated supplies in the delta, not only to meet the requirements of the San Joaquin Delta and adjacent uplands in the northerly end of the San Joaquin River Basin but also for conveyance through the San Joaquin River Pumping System for use in the San Joaquin Valley.

Operation and Accomplishments—Under the proposed plan of complete initial development, the requirements of the Sacramento-San Joaquin Delta, the adjacent delta uplands, and the industrial and agricultural areas south of Suisun Bay in the upper San Francisco Bay region would be fully met by regulated supplies furnished from Kennett Reservoir to supplement the inflow into the delta from unregulated streams and those regulated by present developments and under conditions of operation for complete initial development from the Sacramento and San Joaquin river systems. This would include the provision of regulated flows required to control salinity at the lower end of the delta to maintain continuous fresh water in the delta channels. The water requirements supplied in the Sacramento-San Joaquin delta region for these purposes would be as previously set forth in the discussion of the immediate initial development (see Table 159). In addition to meeting these requirements there would have been made available in the delta channels from the surplus shown in Table 159, during the period 1919–1928, an irrigation supply without deficiency sufficient in amount to meet the full requirements of the "crop lands" in the lower San Joaquin Valley above the mouth of the Merced River now being served by San Joaquin River water. This supply would be conveyed through the San Joaquin River Pumping System to Mendota and substituted for the San Joaquin River water now used on the crop lands. By means of this exchange and with the grass land rights purchased, practically the entire flow of the San Joaquin River would be available for regulation in and diversion from Friant Reservoir for use in the upper San Joaquin Valley. With the entire impaired flow of the San Joaquin River available for regulation in Friant Reservoir, the reservoir would be operated in the same manner as under ultimate development with detailed operation and utilization of water supplies as set forth in Chapter VII. Based upon the run-off during the 40-year period 1889–1929, the average seasonal supply from Friant Reservoir for the upper San Joaquin Valley would have been 1,726,000 acre-feet. For the twelve-year period 1917–1929, the combined average seasonal utilizable yield from the local streams of the upper San Joaquin Valley comprising the Chowchilla, Fresno, Kings, Kaweah, Tule and Kern rivers, through direct surface application and underground storage and pumping would have been about 2,208,000 acre-feet. For the same period, the combined average seasonal utilizable yield from the San Joaquin River and local streams would have amounted to 3,574,000 acre-feet, or sufficient supply for the irrigation of 1,787,000 acres, or about one and one-half times the irrigated area now supplied from these local streams on the east side of the upper San Joaquin Valley.

In the actual operation of the San Joaquin River Pumping System, return flow and surplus waters from the lower San Joaquin Valley would be intercepted above the several dams of the pumping system in order to reduce pumping charges to a minimum. Such amounts of intercepted surplus and return flow waters which would have reached the delta if not intercepted would have to be replaced in the delta channels by Sacramento River Basin water in order to meet the full requirements of the delta region. Therefore, the supplemental water requirements to be supplied from the Sacramento River Basin under the plan of complete initial development would not be reduced in amount by the interception and utilization of these surplus and return flow waters. The only effect would be a reduction in pumping costs in the San Joaquin River Pumping System. During certain months of the year the surplus and return flow waters from the lower San Joaquin Valley would be sufficient to meet the requirements to be served under the San Joaquin River Pumping System including the areas now served by pumping diversions on the west side of the lower San Joaquin Valley between Newman and Paradise Dam. During other months of the year, the larger portion or all of the water supply required for the crop lands above the mouth of the Merced River would have to be diverted from the delta channels from supplies furnished from the Sacramento River Basin.

In order to determine the proper and economic size of pumping installation for each lift and to estimate the electrical energy required for pumping, a detailed study for the period 1917–1929 was made of the amounts and time of occurrence of the return water and other flows which could be intercepted and utilized. In making this study, it was assumed that the present conditions of irrigation development and operation would have existed during the period studied and that the Hetch Hetchy Project of the City and County of San Francisco would have been in operation and diverting water from the Tuolumne watershed in accord with the anticipated demands for the year 1940.

The monthly contributions of surplus and return flow waters from the lower San Joaquin Valley for each season during the twelve-year period 1917–1929, are set forth in Table 183. The monthly demands of the "crop lands" also are given. The quantities shown for inflow to the delta are the estimated amounts of surplus and return flow waters as measured immediately above Dam No. 1 of the San Joaquin River Pumping System. They comprise the estimated flow of the San Joaquin River above Merced River, adjusted for the operation of Friant Reservoir and diversions through the Madera and San Joaquin River-Kern County canals and for greater return flow due to increased supply to the lower San Joaquin Valley "crop lands" under the plan

TABLE 183

UTILIZATION OF RETURN FLOW AND UNREGULATED SURPLUS WATERS IN LOWER SAN JOAQUIN RIVER UNDER IRRIGATION AND STORAGE CONDITIONS AS OF 1929 AND MUNICIPAL DIVERSIONS AS OF 1940 TO SUPPLY LOWER SAN JOAQUIN VALLEY CROP LANDS

Quantities in acre-feet

Season	Item	October	November	December	January	February	March	April	May	June	July	August	September	Season
	Demand of Lower San Joaquin Valley crop lands	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700
1917-18	Inflow to delta*	72,200	84,100	84,100	83,500	98,000	384,800	495,900	484,800	441,800	95,200	53,300	53,800	2,431,500
	Excess	44,300	75,700	77,700	73,500	70,100	333,200	381,200	326,100	278,800	0	0	0	1,660,600
	Deficiency	0	0	0	0	0	0	0	0	0	46,800	55,000	23,000	124,800
1918-19	Inflow to delta*	98,500	79,300	111,500	91,600	108,900	167,100	268,600	616,900	176,300	53,300	59,200	55,000	1,886,200
	Excess	70,600	70,900	105,100	81,600	81,000	115,500	153,900	458,200	13,300	0	0	0	1,150,100
	Deficiency	0	0	0	0	0	0	0	0	0	88,700	49,100	21,800	159,600
1919-20	Inflow to delta*	77,500	82,700	85,500	83,800	79,000	68,900	133,800	405,800	345,500	54,000	54,400	51,800	1,522,700
	Excess	49,600	74,300	79,100	73,800	51,100	17,300	19,100	247,100	182,500	0	0	0	793,900
	Deficiency	0	0	0	0	0	0	0	0	0	88,000	53,900	25,000	166,900
1920-21	Inflow to delta*	75,900	75,900	105,600	252,000	279,600	312,400	379,500	676,500	679,700	104,600	49,300	51,500	3,042,500
	Excess	48,000	67,500	99,200	242,000	251,700	260,800	264,800	517,800	516,700	0	0	0	2,268,500
	Deficiency	0	0	0	0	0	0	0	0	0	37,400	59,000	25,300	121,700
1921-22	Inflow to delta*	72,600	86,000	91,000	249,200	449,700	527,900	519,100	1,180,800	1,517,300	368,100	51,800	55,000	5,168,500
	Excess	44,700	77,600	84,600	239,200	421,800	476,300	404,400	1,022,100	1,354,300	226,100	0	0	4,351,100
	Deficiency	0	0	0	0	0	0	0	0	0	0	56,500	21,800	78,300
1922-23	Inflow to delta*	72,100	88,300	189,500	224,000	235,500	156,800	524,900	792,000	462,100	186,600	53,000	60,300	3,045,100
	Excess	44,200	79,900	183,100	214,000	207,600	105,200	410,200	633,300	299,100	44,600	0	0	2,221,200
	Deficiency	0	0	0	0	0	0	0	0	0	0	55,300	16,500	71,800
1923-24	Inflow to delta*	77,600	84,700	96,600	91,600	98,200	45,300	71,400	46,300	35,400	47,000	26,600	29,700	750,400
	Excess	49,700	76,300	90,200	81,600	70,300	0	0	0	0	0	0	0	368,100
	Deficiency	0	0	0	0	0	6,300	43,300	112,400	127,600	95,000	81,700	47,100	513,400
1924-25	Inflow to delta*	37,000	74,200	80,500	40,400	163,800	171,700	448,300	765,600	398,300	71,200	45,300	55,900	2,352,200
	Excess	9,100	65,800	74,100	30,400	135,900	120,100	333,600	606,900	235,300	0	0	0	1,611,200
	Deficiency	0	0	0	0	0	0	0	0	0	70,800	63,000	20,900	154,700
1925-26	Inflow to delta*	66,300	79,000	96,600	72,500	125,300	119,700	351,000	381,700	51,200	43,500	32,700	43,100	1,462,600
	Excess	38,400	70,600	90,200	62,500	97,400	68,100	236,300	223,000	0	0	0	0	886,500
	[illegible]	[illegible]	0	0	0	[illegible]	0	0	0	118,800	98,500	75,600	33,700	319,600

1926-27	Inflow to delta*	29,900	60,400	117,900	129,300	337,600	351,500	504,600	782,700	731,000	98,500	41,900	45,400	3,230,700
	Excess	2,000	52,000	111,500	119,300	309,700	299,900	389,900	624,000	568,000	0	0	0	2,476,300
	Deficiency	0	0	0	0	0	0	0	0	0	43,500	66,400	31,400	141,300
1927-28	Inflow to delta*	68,200	135,600	126,700	116,700	127,700	434,700	470,300	515,600	120,400	42,600	35,900	44,600	2,239,000
	Excess	40,300	127,200	120,300	106,700	99,800	383,100	355,600	356,900	0	0	0	0	1,589,900
	Deficiency	0	0	0	0	0	0	0	0	42,600	99,400	72,400	32,200	246,600
1928-29	Inflow to delta*	105,600	105,600	75,500	99,900	115,200	97,900	76,600	169,800	101,700	30,700	24,300	30,800	1,033,600
	Excess	77,700	97,200	69,100	89,900	87,300	46,300	0	11,100	0	0	0	0	478,600
	Deficiency	0	0	0	0	0	0	38,100	0	61,300	111,300	84,000	46,000	340,700
Mean, 1917-1929	Inflow to delta*	71,100	86,300	105,100	127,900	184,900	236,600	353,700	568,200	421,700	99,600	44,000	48,100	2,347,200
	Excess	43,200	77,900	98,700	117,900	157,000	185,500	245,800	418,900	287,300	22,600	0	0	1,654,800
	Deficiency	0	0	0	0	0	500	6,800	9,400	28,600	65,000	64,300	28,700	203,300

* Quantities shown for inflow to the delta are the estimated amounts of surplus and return flow waters as measured immediately above Dam No. 1 of the San Joaquin River Pumping System. They comprise the estimated flow of the San Joaquin River above Merced River, adjusted for the operation of Friant Reservoir and diversions through the Madera and San Joaquin River-Kern County canals and for greater return flow due to increased supply to the lower San Joaquin Valley "crop lands" under the plan of complete initial development; and the estimated flow of the Merced, Tuolumne, and Stanislaus rivers at their junction with the San Joaquin River under irrigation and storage conditions as of 1929 and municipal diversions as of 1940, with deductions for west side pumping diversions from Patterson Colony to Banta-Carbona Irrigation District, inclusive.

of complete initial development; and the estimated flow of the Merced, Tuolumne, and Stanislaus rivers at their junctions with the San Joaquin River under irrigation and storage conditions as of 1929 and municipal diversions as of 1940, with deductions for west side pumping diversions from Patterson Colony to Banta-Carbona Irrigation District, inclusive. The excesses shown are the residual amounts of return flow and surplus waters which would have reached the delta after deducting the demands of the lower San Joaquin Valley "crop lands." The deficiencies shown are the amounts of water which would have been required in addition to surplus and return flow waters available for utilization and which would have been supplied by importation from the delta channels through the San Joaquin River Pumping System, in order to satisfy completely the demands of the "crop lands."

Based upon similar analyses of amounts of excesses and deficiencies in surplus and return flow waters as related to requirements of "crop lands" and west side pumping diversions above each dam of the pumping system, the amounts of water to be pumped through each pumping lift were determined. In Table 184, there are set forth by months for the period 1917–1929 the amounts of water which would have been pumped through each lift under conditions of complete initial development and the required installed capacities of pumps and motors for each lift. The table also gives, by seasons, the electrical energy which would have been consumed at each pumping plant based on an assumed over-all plant efficiency of 60 per cent. At the foot of the table, a summary is given showing for each lift the installed capacities of pumps and motors, the total and average seasonal amounts of water pumped, the total and average seasonal amounts of electrical energy consumed and the average seasonal energy costs for the twelve-year period.

PUMPING LIFTS AND CAPACITIES, AMOUNTS OF WATER PUMPED AND ENERGY CONSUMPTION FOR SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF COMPLETE INITIAL DEVELOPMENT, 1917-1929

PUMPING PLANT AT DAM No. 1

Height of lift, 18 feet. Installed capacity, 2,000 second-feet, 5,500 horse power.

Season	Water pumped, in acre-feet													Energy consumption, in kilowatt hours
	October	November	December	January	February	March	April	May	June	July	August	September	Totals	
1917-18	0	0	0	0	0	0	0	0	0	46,800	55,000	23,000	124,800	3,835,700
1918-19	0	0	0	0	0	0	0	0	0	88,700	49,100	21,800	159,600	4,905,300
1919-20	0	0	0	0	0	0	0	0	0	88,000	53,900	25,000	166,900	5,129,700
1920-21	0	0	0	0	0	0	0	0	0	37,400	59,000	25,300	121,700	3,740,400
1921-22	0	0	0	0	0	0	0	0	0	0	56,500	21,800	78,300	2,406,600
1922-23	0	0	0	0	0	0	0	0	0	0	55,300	16,500	71,800	2,206,800
1923-24	0	0	0	0	0	6,300	43,300	112,400	119,000	103,600	81,700	47,100	513,400	15,779,300
1924-25	0	0	0	0	0	0	0	0	0	70,800	63,000	20,900	154,700	4,754,700
1925-26	0	0	0	0	0	0	0	0	111,800	98,500	75,600	33,700	319,600	9,822,900
1926-27	0	0	0	0	0	0	0	0	0	43,500	66,400	31,400	141,300	4,342,900
1927-28	0	0	0	0	0	0	0	0	42,600	99,400	72,400	32,200	246,600	7,579,300
1928-29	0	0	0	0	0	0	38,100	0	61,300	111,300	84,000	46,000	340,700	10,471,400
Totals													2,439,100	74,975,000
Average													203,300	6,248,000

PUMPING PLANT AT DAM No. 2

Height of lift, 12.9 feet. Installed capacity, 2,000 second-feet, 4,000 horse power.

Season	October	November	December	January	February	March	April	May	June	July	August	September	Totals	Energy consumption, in kilowatt hours
1917-18	0	0	0	0	0	0	0	0	0	44,500	53,100	23,100	120,700	2,658,600
1918-19	0	0	0	0	0	0	0	0	0	87,600	48,200	22,800	158,600	3,493,400
1919-20	0	0	0	0	0	0	42,600	0	0	86,700	52,800	25,800	207,900	4,579,400
1920-21	0	0	0	0	0	0	0	0	0	38,400	57,600	25,900	121,900	2,685,100
1921-22	0	0	0	0	0	0	0	0	0	0	54,900	22,200	77,100	1,698,300
1922-23	0	0	0	0	0	0	0	0	0	0	53,700	17,000	70,700	1,557,300
1923-24	0	0	0	0	0	8,200	43,500	105,500	119,000	96,800	79,300	46,900	499,200	10,995,800
1924-25	0	0	0	0	0	0	0	0	0	70,000	61,000	21,000	152,000	3,348,100
1925-26	0	0	0	0	0	0	0	0	108,600	96,600	73,900	34,100	313,200	6,898,800
1926-27	400	0	0	0	0	0	0	0	0	45,400	65,400	33,600	144,800	3,189,500
1927-28	0	0	0	0	0	0	0	0	53,400	96,600	72,000	33,400	255,400	5,625,600
1928-29	0	0	0	0	0	0	38,700	23,000	90,400	112,500	83,300	48,500	396,400	8,731,400
Totals													2,517,900	55,461,300
Average													209,800	4,622,000

TABLE 184—Continued

PUMPING LIFTS AND CAPACITIES, AMOUNTS OF WATER PUMPED AND ENERGY CONSUMPTION FOR SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF COMPLETE INITIAL DEVELOPMENT, 1917-1929

PUMPING PLANTS AT DAMS No. 3 AND No. 4

Height of lift, 12.9 feet. Installed capacity, 2,500 second-feet, 4,900 horse power.

Season	Water pumped, in acre-feet													Energy consumption, in kilowatt hours
	October	November	December	January	February	March	April	May	June	July	August	September	Totals	
1917–18	6,200	0	4,100	7,300	14,800	0	0	0	0	68,700	73,300	43,100	217,500	4,790,800
1918–19	0	2,700	0	0	0	0	40,300	20,400	20,500	111,800	68,400	42,800	306,900	6,760,000
1919–20	1,800	0	1,800	2,600	8,000	16,500	58,500	136,000	8,600	110,900	73,000	45,700	463,400	10,207,200
1920–21	3,300	6,600	1,800	0	0	0	15,000	0	0	62,600	77,800	45,800	212,900	4,689,500
1921–22	6,400	0	5,300	0	0	0	0	0	0	0	75,100	42,100	128,900	2,839,200
1922–23	6,700	0	0	0	0	6,200	0	0	0	52,100	73,900	36,900	175,800	3,872,300
1923–24	1,300	0	500	2,800	0	32,100	58,500	116,300	143,200	115,000	98,300	65,700	633,700	13,958,400
1924–25	13,700	0	0	0	10,600	37,900	60,200	0	50,300	93,500	78,400	43,100	387,700	8,539,800
1925–26	2,400	0	0	0	0	30,200	35,400	0	130,100	121,500	94,600	54,500	468,700	10,323,900
1926–27	20,300	0	0	0	0	0	0	0	0	75,000	86,000	55,200	236,500	5,209,300
1927–28	11,000	0	0	0	0	0	10,400	26,300	103,000	121,200	92,500	54,300	418,700	9,222,600
1928–29	11,100	0	0	0	0	11,900	82,600	137,400	136,800	135,800	102,700	67,700	686,000	15,110,300
Totals													4,336,700	95,523,300
Average													361,400	7,960,000

PUMPING PLANT AT DAM No. 5

Height of lift, 12.9 feet. Installed capacity, 2,500 second-feet, 4,900 horse power.

Season	October	November	December	January	February	March	April	May	June	July	August	September	Totals	Energy consumption, in kilowatt hours
1917–18	4,300	0	4,600	7,800	15,300	0	0	0	0	60,800	66,800	38,900	198,500	4,372,300
1918–19	0	3,200	0	0	0	0	37,400	10,700	12,000	103,900	61,900	38,600	267,700	5,896,600
1919–20	0	500	2,300	3,100	8,500	14,500	55,600	126,300	100	103,000	66,500	41,500	421,900	9,293,100
1920–21	1,400	7,100	2,300	0	0	0	12,100	0	0	54,700	71,300	41,600	190,500	4,196,100
1921–22	4,500	0	5,800	0	0	0	0	0	0	0	68,600	37,900	116,800	2,572,700
1922–23	4,800	0	0	0	0	4,200	0	0	0	44,200	67,400	32,700	153,300	3,376,700
1923–24	0	0	1,000	3,300	0	30,100	55,600	106,600	134,700	107,100	91,800	61,500	591,700	13,033,200
1924–25	11,800	0	0	0	11,100	35,900	57,300	0	41,800	85,600	71,900	38,900	354,300	7,804,100
1925–26	500	0	0	0	0	28,200	32,500	0	121,600	113,600	88,100	50,300	434,800	9,577,200
1926–27	18,400	200	0	0	0	0	0	0	0	67,100	79,500	51,000	216,200	4,762,200
1927–28	9,100	0	0	0	0	0	7,500	16,600	94,500	113,300	86,000	50,100	377,100	8,306,300
1928–29	9,200	0	0	0	0	9,900	79,700	127,700	128,300	127,900	96,200	63,500	642,400	14,150,000
Totals													3,965,200	87,340,500
Average													330,400	7,278,000

PUMPING PLANTS AT CANAL LIFTS No. 6, No. 7 AND No. 8

Height of lift, 26.5 feet. Installed capacity, 3,000 second-feet, 12,000 horse power.

Season	Water pumped, in acre-feet													Energy consumption, in kilowatt hours
	October	November	December	January	February	March	April	May	June	July	August	September	Totals	
1917-18	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1918-19	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1919-20	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1920-21	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1921-22	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	0	142,000	108,300	76,800	732,700	33,153,800
1922-23	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1923-24	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1924-25	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1925-26	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1926-27	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1927-28	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
1928-29	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700	40,529,300
Totals													10,585,400	478,976,100
Average													882,100	39,914,000

PUMPING PLANTS AT CANAL LIFTS No. 9 AND No. 10

Height of lift, 26.5 feet. Installed capacity, 2,000 second-feet, 8,000 horse power.

1917-18	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1918-19	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1919-20	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1920-21	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1921-22	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	0	94,700	72,200	51,200	488,400	22,099,000
1922-23	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1923-24	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1924-25	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1925-26	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1926-27	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1927-28	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
1928-29	18,600	5,600	4,300	6,600	18,600	34,400	76,400	105,800	108,700	94,700	72,200	51,200	597,100	27,018,000
Totals													7,056,500	319,297,000
Average													588,000	26,608,000

TABLE 184—Continued

PUMPING LIFTS AND CAPACITIES, AMOUNTS OF WATER PUMPED AND ENERGY CONSUMPTION FOR FOR SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF COMPLETE INITIAL DEVELOPMENT, 1917-1929

SUMMARY

Pumping plant	Height of lift, in feet	Installed capacity		12 year total		Average seasonal		
		Pumps, second-feet	Motors, horse power	Water pumped, in acre-feet	Energy consumption, in kilowatt hours	Water pumped, in acre-feet	Energy consumption, in kilowatt hours	Energy cost, at $0.0055 per kilowatt hour
No. 1	18.0	2,000	5,500	2,439,000	74,975,000	203,000	6,248,000	$34,000
No. 2	12.9	2,000	4,000	2,518,000	55,461,000	210,000	4,622,000	25,000
No. 3	12.9	2,500	4,900	4,337,000	95,523,000	361,000	7,960,000	44,000
No. 4	12.9	2,500	4,900	4,337,000	95,523,000	362,000	7,960,000	44,000
No. 5	12.9	2,500	4,900	3,965,000	87,340,000	330,000	7,278,000	40,000
No. 6	26.5	3,000	12,000	10,585,000	478,976,000	882,000	39,914,000	220,000
No. 7	26.5	3,000	12,000	10,586,000	478,976,000	882,000	39,914,000	220,000
No. 8	26.5	3,000	12,000	10,585,000	478,976,000	882,000	39,914,000	220,000
No. 9	26.5	2,000	8,000	7,057,000	319,297,000	588,000	26,608,000	146,000
No. 10	26.5	2,000	8,000	7,056,000	319,297,000	588,000	26,608,000	146,000
Totals	202.1		76,200		2,484,344,000		207,026,000	$1,139,000

Economic and Financial Aspects—Consideration of the economic and financial aspects of the proposed plan for complete initial development in the San Joaquin River Basin must be combined with the plan for the Sacramento River Basin because the initial units in both basins are interdependent and interrelated and together comprise a unified project of coordinate development of the complete initial State Water Plan in the entire Great Central Valley. The major units of the proposed complete initial development for the entire Great Central Valley, including a conduit to deliver water from the delta to the upper San Francisco Bay region, are as follows:

1. Kennett Reservoir and Power Plant, capacity 2,940,000 acre-feet.
2. Sacramento-San Joaquin Delta Cross Channel.
3. Contra Costa County Conduit, capacity 120 second-feet.
4. San Joaquin River Pumping System, capacity 3000 second-feet.
5. Friant Reservoir and Power Plant, gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet.
6. Madera Canal, capacity 1500 second-feet.
7. San Joaquin River-Kern County Canal, capacity 3000 second-feet.
8. Magunden-Edison Pumping System, capacity 20 second-feet.

The capital and gross annual costs and anticipated revenues under the plan of complete initial development in the Great Central Valley are presented in Table 185. The annual costs include operation and maintenance charges, interest at 4½ per cent per annum, amortization on a forty-year sinking fund basis at 4 per cent, and depreciation on a 4 per cent sinking fund basis with different lengths of service for the various elements of each unit. The basis for estimating the anticipated revenues from the sale of water and power have been previously set forth under the presentation of the economic and financial aspects of the immediate initial development. Revenue from the sale of water in the upper San Joaquin Valley is based upon the average seasonal supply that would have been made available during the forty-year period 1889–1929 totaling 1,720,000 acre-feet and applying thereto a rate of $3.00 per acre-foot. The annual output of electric energy would be slightly reduced at Kennett Reservoir and would be considerably reduced at Friant Reservoir as compared to the immediate initial development. Total revenues are estimated as the total amounts which would be realized when the supplies provided are fully utilized and the water and power sold at the unit values estimated.

With State financing at 4½ per cent interest and amortization of the capital investment in forty years, the gross annual cost exceeds the anticipated revenues from the sale of water and power by $2,816,000 or practically the same amount as under the immediate initial development. Possible revenue from sale of stored water from Kennett Reservoir for use in the Sacramento Valley and Sacramento-San Joaquin Delta would reduce the net annual cost by about $420,000. In addition to the direct anticipated revenues, it is believed that the large benefits which would accrue to many interests, not only local but also national and state-wide, might reasonably justify the anticipation of direct contributions by the Federal and State governments to defray a portion of the cost of the project. These have been pointed out in the discussion previously presented for the immediate initial development. With such direct contributions and with the further possibility of financing the project at a lower rate of interest than that assumed and with the amortization period increased, the annual cost, including interest and amortization on capital expenditures to be directly borne by the project, might be reduced to such an extent that the revenues would be sufficient. Analyses were made of several plans of financing based upon various interest and sinking fund rates, amortization periods and Federal and State contributions. The data prepared are similar to those set forth in Table 169 and are presented in Table 186.

TABLE 185

COSTS AND REVENUES COMPLETE INITIAL DEVELOPMENT OF STATE WATER PLAN IN GREAT CENTRAL VALLEY

Item	Capital cost	Gross annual cost	
Capital and annual cost—			
Kennett reservoir and power plant	$84,000,000	$5,297,000	
Sacramento-San Joaquin Delta cross channel	4,000,000	300,000	
Contra Costa County conduit	2,500,000	300,000	
San Joaquin River pumping system	15,000,000	2,500,000	
Friant reservoir and power plant	14,500,000	885,000	
Madera canal	2,500,000	213,000	
San Joaquin River-Kern County canal	27,300,000	2,225,000	
Magunden-Edison pumping system	100,000	18,000	
Right of ways, water rights and general expense	8,000,000	444,000	
Total	$157,900,000	$12,182,000	$12,182,000
Annual revenues—			
Electric energy sales:			
1,581,100,000 kilowatt hours at $0.00242	$3,826,000		
23,000,000 kilowatt hours at $0.0035	80,000		
Total electric energy sales		$3,906,000	
Water sales:			
1,720,000 acre-feet for upper San Joaquin Valley, based on average for forty-year period, 1889-1929, at $3 per acre-foot	$5,160,000		
43,500 acre-feet for Contra Costa County conduit at $6.90 per acre-foot	300,000		
Total water sales		5,460,000	
Total revenues, electric energy and water		$9,366,000	9,366,000
Net annual cost in excess of revenues			$2,816,000

TABLE 186

FINANCIAL ANALYSES OF PLAN OF COMPLETE INITIAL DEVELOPMENT GREAT CENTRAL VALLEY PROJECT WITH VARIOUS ASSUMED INTEREST RATES, AMORTIZATION PERIODS AND STATE AND FEDERAL CONTRIBUTIONS

Basis of financing	Capital cost	Gross annual cost	Annual direct revenue from water and power sales[1]	Net annual cost (—), or return (+)
Without Direct Federal or State Contributions				
Plan 1. Interest at 4½ per cent and 40-year amortization on a 4 per cent sinking fund basis	$157,900,000	$12,182,000	$9,786,000	—$2,396,000
Plan 2. Interest at 4½ per cent and 50-year amortization on a 4 per cent sinking fund basis	157,900,000	11,556,000	9,786,000	—1,770,000
Plan 3. Interest at 4½ per cent and 70-year amortization on a 4 per cent sinking fund basis	157,900,000	10,956,000	9,786,000	—1,170,000
Plan 4. Interest at 4 per cent and 50-year amortization on a 4 per cent sinking fund basis	156,200,000	10,649,000	9,786,000	—863,000
Plan 5. Interest at 3½ per cent and 50-year amortization on a 3½ per cent sinking fund basis	154,700,000	9,945,000	9,786,000	—159,000
Plan 6. Interest at 3 per cent and 50-year amortization on a 3 per cent sinking fund basis	152,900,000	9,253,000	9,786,000	+533,000
Plan 7. No interest and repayment of principal sum in 40 equal annual installments	142,900,000	6,673,000	9,786,000	+3,113,000
With Direct Federal and State Contributions				
Plan 8. Same as Plan 1, with direct Federal contribution of $6,000,000 in the interest of navigation and State contribution of $3,400,000 for the relocation of State Highway above Kennett Reservoir	*148,500,000	11,658,000	9,786,000	—1,872,000
Plan 9. Same as Plan 2, with Federal and State contributions as in Plan 8	*148,500,000	11,071,000	9,786,000	—1,285,000
Plan 10. Same as Plan 3, with Federal and State contributions as in Plan 8	*148,500,000	10,507,000	9,786,000	—721,000
Plan 11. Interest at 4½ per cent and refunding bonds, with same Federal and State contributions as in Plan 8	*148,500,000	10,099,000	9,786,000	—313,000
Plan 12. Same as Plan 5 with Federal and State contributions as in Plan 8	*145,300,000	9,613,000	9,786,000	+173,000
Plan 13. Same as Plan 12 with Federal contribution increased to $20,000,000	*131,300,000	9,016,000	9,786,000	+770,000

* Direct Federal and State contributions not included.

[1] Includes a revenue of $420,000 for sale of stored water in Sacramento Valley and Sacramento-San Joaquin Delta, not shown in Table 185.

NOTE.—If financed under the provisions of Title II of the National Industrial Recovery Act of 1933, with a direct federal contribution of 30 per cent of the cost of labor and materials and a Federal loan to finance the balance of the cost with interest at 4 per cent and amortization on a 4 per cent sinking fund basis in 50 years, the gross annual cost of the project for complete initial development would be considerably less than the anticipated annual revenue from water and power sales.

CHAPTER IX

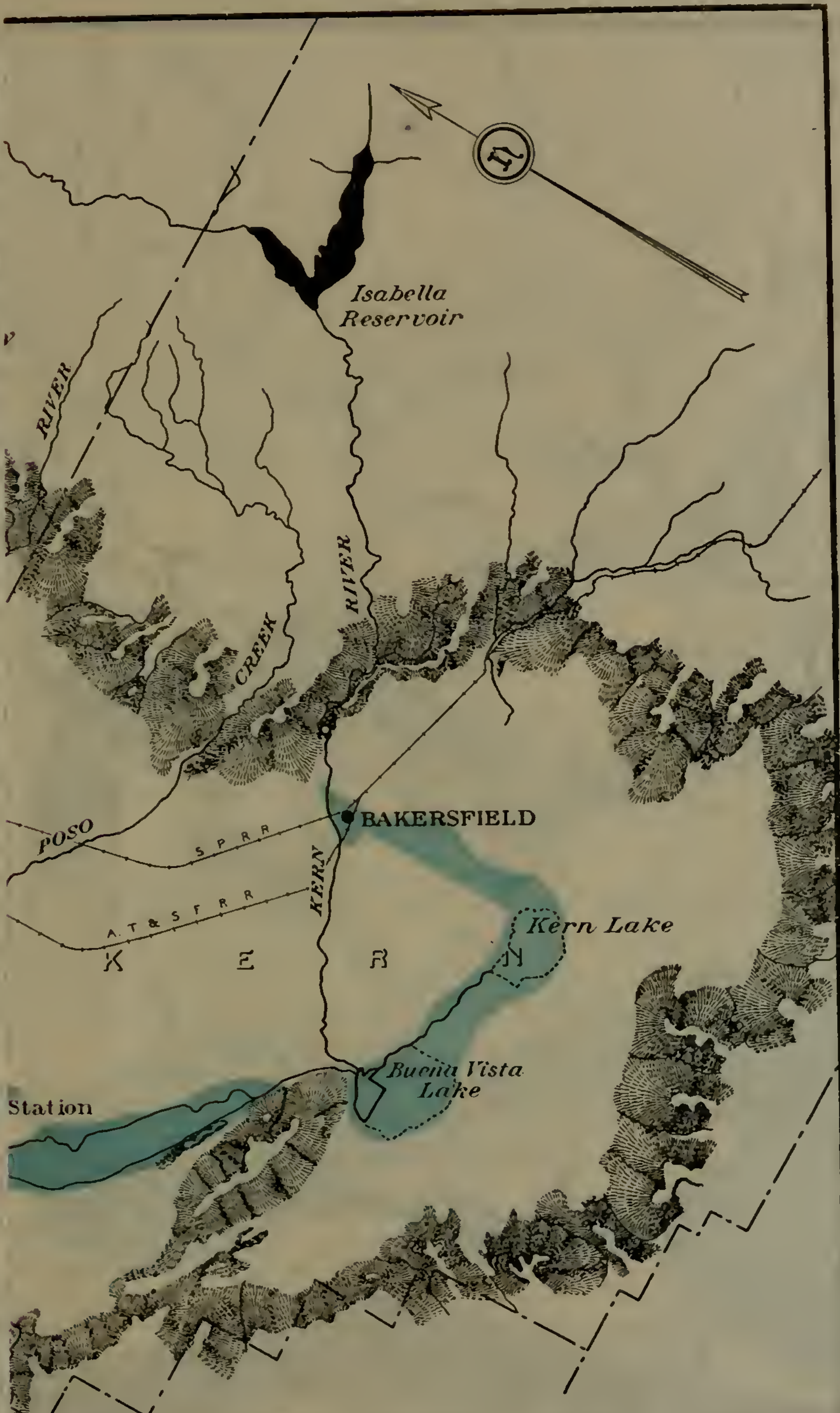
FLOOD CONTROL

Prior to the settlement of the San Joaquin Valley by white men and the beginning of its use for agriculture, large areas of land were subject to annual or periodic inundation by flood waters from the San Joaquin River and its tributaries and the streams flowing into Tulare and Buena Vista lakes. It is difficult to determine the exact boundaries of these overflow areas because of the lack of authentic records. A map of the land subject to overflow has been prepared, however, utilizing the best available data, and is presented herewith as Plate LXXIII, "Lands Naturally Subject to Overflow in the San Joaquin Valley." The data used in the preparation of this plate were obtained from a map made by Wm. Ham. Hall, State Engineer, in 1887, and from maps of the Sacramento-San Joaquin Drainage District and proposed extensions of that district. The purpose of the plate is to show in a general way the locations and magnitudes of the areas in the San Joaquin Valley naturally subject to inundation. Small areas may be included within the boundary which are not or were not subject to overflow and, on the other hand, small areas which may have been overflowed or are subject to overflow may have been omitted. No attempt has been made to indicate overflow lands in the Kaweah and Tule river deltas as they are scattering tracts. The area subject to inundation by floods of the Calaveras River and adjacent minor streams is shown on this map although it was omitted from a map in a previous report * which shows the area in the vicinity of Stockton subject only to backwater flooding from the delta channels. The total area of lands naturally subject to overflow shown on this map is somewhat more than one and three-quarters million acres.

The overflow lands, due to their character or position, have been divided into four groups. In the first group are included all lands in the upper San Joaquin Valley south of the San Joaquin River; in the second group, the lands lying along the San Joaquin River from Herndon to the mouth of the Merced River; in the third group, the lands along the San Joaquin River from the mouth of the Merced River to Paradise Dam at the head of the San Joaquin Delta; and in the last group, the lands in the San Joaquin Delta, and bordering lands.

The control of floods in the San Joaquin Valley is closely associated with the conservation features of the State Water Plan since much of the land on the valley floor which ultimately would receive the regulated water supplies made available through the operation of the State Water Plan lies within the area which is subject to periodic inundation. These lands which will be developed through increased water supplies and will have increased property values must be protected from flood hazard. With the larger storage reservoirs of the State Water Plan constructed and operated for flood control, a substantially increased degree of

* Bulletin No. 27, "Variation and Control of Salinity in the Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.



LANDS NATURALLY SUBJECT TO OVERFLOW

IN THE

SAN JOAQUIN VALLEY

CHAPTER IX

FLOOD CONTROL

Prior to the settlement of the San Joaquin Valley by white men and the beginning of its use for agriculture, large areas of land were subject to annual or periodic inundation by flood waters from the San Joaquin River and its tributaries and the streams flowing into Tulare and Buena Vista lakes. It is difficult to determine the exact boundaries of these overflow areas because of the lack of authentic records. A map of the land subject to overflow has been prepared, however, utilizing the best available data, and is presented herewith as Plate LXXIII, "Lands Naturally Subject to Overflow in the San Joaquin Valley." The data used in the preparation of this plate were obtained from a map made by Wm. Ham. Hall, State Engineer, in 1887, and from maps of the Sacramento-San Joaquin Drainage District and proposed extensions of that district. The purpose of the plate is to show in a general way the locations and magnitudes of the areas in the San Joaquin Valley naturally subject to inundation. Small areas may be included within the boundary which are not or were not subject to overflow and, on the other hand, small areas which may have been overflowed or are subject to overflow may have been omitted. No attempt has been made to indicate overflow lands in the Kaweah and Tule river deltas as they are scattering tracts. The area subject to inundation by floods of the Calaveras River and adjacent minor streams is shown on this map although it was omitted from a map in a previous report * which shows the area in the vicinity of Stockton subject only to backwater flooding from the delta channels. The total area of lands naturally subject to overflow shown on this map is somewhat more than one and three-quarters million acres.

The overflow lands, due to their character or position, have been divided into four groups. In the first group are included all lands in the upper San Joaquin Valley south of the San Joaquin River; in the second group, the lands lying along the San Joaquin River from Herndon to the mouth of the Merced River; in the third group, the lands along the San Joaquin River from the mouth of the Merced River to Paradise Dam at the head of the San Joaquin Delta; and in the last group, the lands in the San Joaquin Delta, and bordering lands.

The control of floods in the San Joaquin Valley is closely associated with the conservation features of the State Water Plan since much of the land on the valley floor which ultimately would receive the regulated water supplies made available through the operation of the State Water Plan lies within the area which is subject to periodic inundation. These lands which will be developed through increased water supplies and will have increased property values must be protected from flood hazard. With the larger storage reservoirs of the State Water Plan constructed and operated for flood control, a substantially increased degree of

* Bulletin No. 27, "Variation and Control of Salinity in the Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.


LANDS NATURALLY SUBJECT
TO OVERFLOW
IN THE
SAN JOAQUIN VALLEY
o Indicates gaging station
SCALE OF MILES
0 8 16 24
Tulare Lake
Kern Lake
Buena Vista Lake
Pine Flat Reservoir
Friant Reservoir
Isabella Reservoir
FRESNO
BAKERSFIELD
STOCKTON
MODESTO
MERCED
MADERA
VISALIA
HANFORD
SAN JOAQUIN
STANISLAUS
TUOLUMNE
MARIPOSA
MERCED
FRESNO
KINGS
KERN
TULARE
MADERA
SAN BENITO
MONTEREY
SANTA CLARA
ALAMEDA
CONTRA COSTA
SACRAMENTO
ELDORADO
CALAVERAS
SOLANO

80997

protection would be furnished to the areas now protected from inundation by existing works, the cost of works to protect additional lands would be greatly reduced, and the lands would be given a greater degree of protection than they would have with works constructed for protection against uncontrolled flows. Not only would the property owners be interested in such developments but also the Federal and State governments which have already contributed, in cooperation with the landowners, large sums of money for the construction of flood control works in the Sacramento Valley. Therefore, it is important and desirable that inquiry be made to determine what additional degree of protection could be afforded areas already leveed, what additional lands could be economically protected and what savings in cost of protection could be effected, by means of the operation of the large major storage reservoirs of the State Water Plan for flood control.

Present Status of Flood Control in the San Joaquin Valley.

The San Joaquin Valley has no flood control project similar to that in the Sacramento Valley which has been adopted by the United States and the State of California and in conformity with which all protection works must be constructed. However, much of the land in the basin subject to inundation now has some degree of protection.

The flood protection works in the San Joaquin Valley have been constructed almost entirely by the landowners with only such assistance from the Federal and State governments as was incidental to the improvement and maintenance of navigation and, in recent years, some assistance from the State in bank and levee protection work. In addition to the Stockton diverting canal hereinafter referred to, the United States has constructed the Stockton Ship Canal and in cooperation with the State has straightened several delta channels. These works undoubtedly have some effect in bettering flowage conditions in the delta.

Upper San Joaquin Valley South of San Joaquin River—Most of the lands subject to inundation in the upper San Joaquin Valley south of the San Joaquin River lie south of the ridge between the San Joaquin and Kings rivers. The connecting channel between the streams south of this ridge and the San Joaquin River is Fresno Slough which joins the river near Mendota. Flood waters in this section of the valley are contributed almost entirely by the Sierra Nevada streams. Most of the flooding under natural conditions, occurred in the Kings, Kaweah, Tule and Kern River deltas and in the beds of Tulare, Kern and Buena Vista lakes. Flooding in the delta areas, however, is of short duration and practically no levees have been constructed except in the Kings River Delta and around Bakersfield. Tulare Lake, lying to the south of the Kings River Delta, receives all waters from the Kings, Kaweah and Tule rivers which are not diverted for irrigation or absorbed into the underground basins, except the amounts which reach Fresno Slough. Some water is also diverted to the lake from Kern River. The lake has covered an area varying from nothing in dry cycles to about 760 square miles in 1862. A large percentage of the area subject to inundation in the Kings River Delta and the bed of Tulare Lake is now included in organized reclamation districts having an aggregate area of about 295,000 acres. Of this area, about 235,000 acres are within levees which give varying degrees of protection. However, much of the leveed land in Tulare Lake might be inundated during wet cycles. The land in the lowest portion of the lake bed has the smallest degree of protection.

Lying to the south of the Kern River Delta, there is a depression in the lowest part of which are the beds of Kern and Buena Vista lakes. Waters of Kern River which naturally reach Kern Lake have been diverted and the lake bed is now dry and under cultivation. Buena Vista Lake receives such flood waters from the Kern River and smaller local streams as are not used for irrigation or absorbed into the underground basins in the Kern River Delta. A portion of this lake has been leveed off and is used as an irrigation storage reservoir and the remainder is now under cultivation. This cultivated portion, however, is available for the storage of water from major floods. Excess waters which can not be stored in Buena Vista Lake are diverted toward Tulare Lake through a channel following the trough of the upper San Joaquin Valley. Lying adjacent to this channel, there is one reclamation district, with an area of about 86,000 acres, which is partially protected by levees. Data on expenditures for flood protection works in the upper San Joaquin Valley are not available.

Upper and Lower San Joaquin Valleys—Herndon to Mouth of Merced River—In the section of the valley lying along the San Joaquin River upstream from the mouth of the Merced River, the flood plain is several miles in width. The total gross area including river and slough channels is about 305,000 acres. Across this flood plain run the winding courses of several sloughs, some of which are as large as the main river channel and in their natural condition carried a large portion of the flood flow. For the most part, such protection as exists in this portion of the valley is afforded by irrigation canal banks constructed along the high ground near the river banks. These works provide protection, of varying degrees, from overflow by the smaller summer and winter floods for about 125,000 acres of land. No costs of flood protection for these lands can be estimated, however, because the primary object of the investment in the canals was for irrigation, and the location of these canals along the river banks was due to considerations of topography and economy.

Lower San Joaquin Valley—Mouth of Merced River to Paradise Dam—The group of overflow lands lying along the San Joaquin River from the mouth of the Merced River to the head of the delta at Paradise Dam has a length of about 34 miles and is so narrow that the gross area is only about 83,000 acres. It is generally conceded that complete or even a high degree of protection against unregulated winter floods through this division of the valley is not economically feasible because a flood channel of sufficient width to accomplish such protection would utilize a large percentage of the best agricultural lands and the burden of cost falling upon the protected area would be greater than the value of the protection. A fair degree of protection from summer and small winter floods is feasible, however, and about 32,000 acres have been wholly or partially protected from such floods at an estimated cost of about $1,500,000.

San Joaquin Delta and Bordering Lands—The San Joaquin Delta comprises low marsh areas consisting of peat and alluvial soils which their natural condition were subject not only to inundation from flood waters but also to tidal overflow since much of the area is below sea level. Bordering the delta there are alluvial rim lands which were subject to inundation from flood waters only. The total area in this group is about 500,000 acres of which several thousand acres lie in the existing waterways.

Protection of the delta lands began early in the history of agriculture in the valley and has been in progress for over sixty years. During this period, practically all of the delta lands have been brought within levees which provide about the maximum degree of protection that can be obtained by this method of flood control. This degree of protection, however, would be far from adequate during a period of major flood occurrence. Levees as a rule follow the winding courses of river channels and connecting sloughs with the result that the delta is made up of a large number of islands. The levees around these islands have been built gradually to the limiting heights that their unstable foundations will support. Although the channels are many, their total flood carrying capacity is far less than the amount they may be called upon to carry in any season of major flood occurrence. Toward the head of the delta the number of channels decreases to two, the natural channel of the main San Joaquin River and an artificial channel called Paradise Cut. Although the levees here are higher than those of the lower delta and might be constructed to even greater heights, the total present safe channel capacity is only about 60,000 second-feet, or less than half the estimated discharge of the 1911 flood through this section of the valley. This capacity is much less than the capacity of the combined lower delta channels. The cost of existing protection works in the San Joaquin Delta is estimated to be about $17,000,000.

The city of Stockton lying on the eastern rim of the delta is endangered not only by San Joaquin River floods but also by the flood waters of the Calaveras River. The Calaveras River channel for a considerable distance below Bellota has practically no carrying capacity and most of the flood waters flow into Mormon Slough and other channels and originally passed through the city of Stockton. Several years ago, the Federal government in order to assist in maintaining navigation in the lower end of Mormon Slough and in Stockton Channel, by keeping debris brought down by floods out of these channels, constructed a canal to the east of Stockton to intercept Mormon and other sloughs and divert their flows back into the Calaveras River at a point where it has a larger capacity, and thence directly into the San Joaquin River. This canal by diverting some of the flood waters of the Calaveras River, affords some protection to the city of Stockton from floods from the east. To further protect itself from such floods, the city in 1930 constructed a reservoir of 76,000 acre-feet capacity on the Calaveras River near Valley Springs for the purpose of controlling its flood flows.

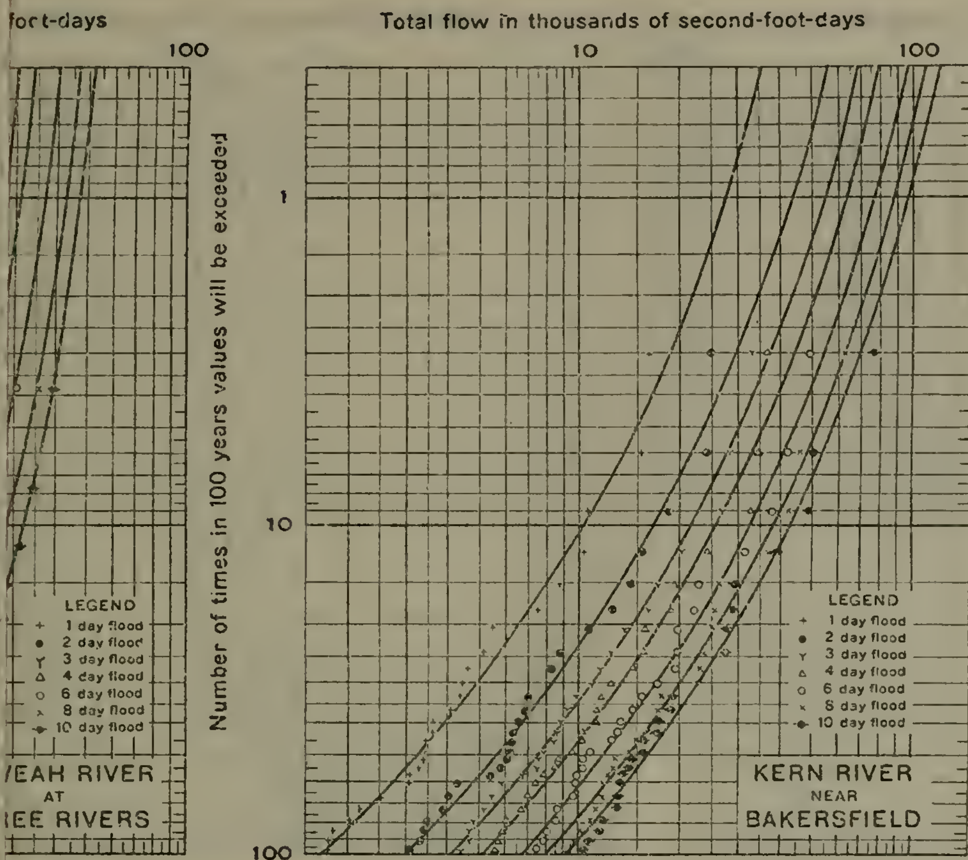
Size and Frequency of Flood Flow.

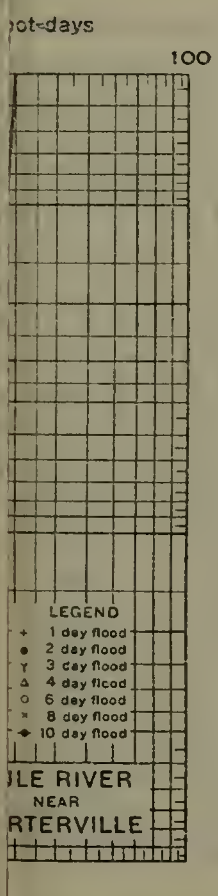
To estimate the probable sizes of floods which may be expected in different sections of the San Joaquin River Basin and the frequency with which they may occur, analyses were made of all available data on flood flows. Studies were made of the flood flows at the gaging station on each of the main streams near the foothill line and also at several selected points of flood concentration on the valley floor.

The data available for these studies are chiefly the records of flood flows obtained by the United States Geological Survey at its gaging stations. The period of record at each station and the maximum and minimum mean daily flows of the major streams of the San Joaquin River Basin have been presented in Chapter II. Data have been obtained for only a relatively short period when consideration is given to the sizes of floods that may occur at long intervals of time such as once in 100 and once in 1000 years. Also, it is difficult to obtain the amounts of flow at times of floods, and the peak and mean daily flows at the crest of a flood must often be estimated from extended rating curves or from stream cross sections and observed surface velocities. While the data, therefore, are not exact and a much longer period of record would be desirable, the studies have been based on these data and are believed to give the best results now obtainable.

Winter and Summer Floods—Floods in the San Joaquin River Basin are of two general classes—winter floods from rain water and summer floods from melting snow. The winter floods occur during the season from November to May and are caused by run-off from rain storms in the lower mountain and valley watersheds or by rain storms combined with melting snow. They are generally characterized by relatively sharp peak flows and the entire flood is of only a few days duration. Flood flows in the San Joaquin River at points on the valley floor, and in the Sacramento-San Joaquin Delta are caused by the concentration of the flood flows of the tributary streams at these points. The peak flow at any point, therefore, depends on the combination of flows from the tributary streams and is subject to wide variation. It is always less than the sum of the peak flows from all of the tributary streams because, on account of the rate and direction of storm travel and the variation in distance of the watersheds of the tributary streams from the point of concentration, the separate peak flows do not all reach the point of concentration at the same time, and also because the peak flows are reduced by channel storage before reaching the point of concentration.

The summer floods occur during the period April to August and are most pronounced on the larger streams whose headwaters are in the high Sierra Nevada. They are caused by the rapid melting of the snow which has accumulated during the winter in the mountains at the higher elevations and are sometimes augmented by spring rains. Summer floods are usually of much greater duration than winter floods and may continue for a period of a month or more. They have no sharp peaks and the maximum flows are not as large as the maximum or peak flows of winter floods. Since the summer floods are of considerable duration, however, the total volume of run-off during such floods may be much greater than in the largest winter floods. Also, since the flows extend over a relatively long period, the flows at points of concentration on the valley floor may more nearly approach the sum of the maximum flows in the tributary streams than they do in winter floods. However, there is practically no run-off from the streams from the lower mountains and the valley floor in the summer and the maximum summer flood flows at the points of concentration on the valley floor are smaller than the peak flows during winter floods.



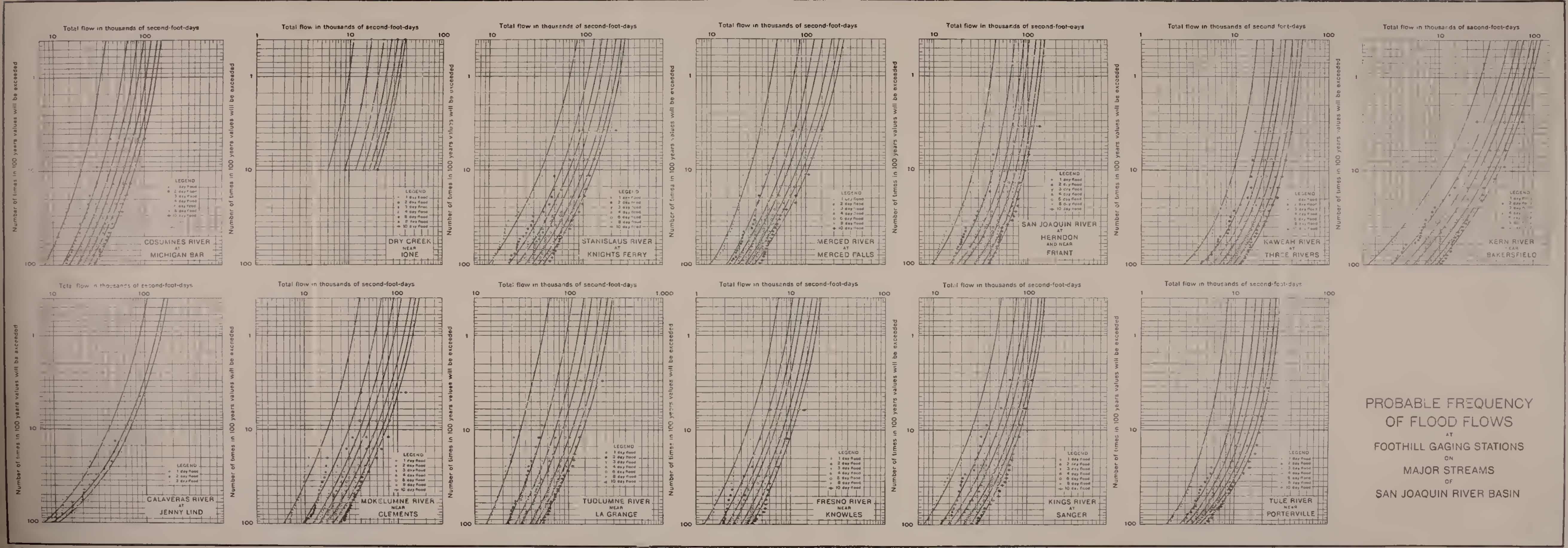


PROBABLE FREQUENCY
OF FLOOD FLOWS
AT
FOOTHILL GAGING STATIONS
ON
MAJOR STREAMS
OF
SAN JOAQUIN RIVER BASIN

The data available for these studies are chiefly the records of flood flows obtained by the United States Geological Survey at its gaging stations. The period of record at each station and the maximum and minimum mean daily flows of the major streams of the San Joaquin River Basin have been presented in Chapter II. Data have been obtained for only a relatively short period when consideration is given to the sizes of floods that may occur at long intervals of time such as once in 100 and once in 1000 years. Also, it is difficult to obtain the amounts of flow at times of floods, and the peak and mean daily flows at the crest of a flood must often be estimated from extended rating curves or from stream cross sections and observed surface velocities. While the data, therefore, are not exact and a much longer period of record would be desirable, the studies have been based on these data and are believed to give the best results now obtainable.

Winter and Summer Floods—Floods in the San Joaquin River Basin are of two general classes—winter floods from rain water and summer floods from melting snow. The winter floods occur during the season from November to May and are caused by run-off from rain storms in the lower mountain and valley watersheds or by rain storms combined with melting snow. They are generally characterized by relatively sharp peak flows and the entire flood is of only a few days duration. Flood flows in the San Joaquin River at points on the valley floor, and in the Sacramento-San Joaquin Delta are caused by the concentration of the flood flows of the tributary streams at these points. The peak flow at any point, therefore, depends on the combination of flows from the tributary streams and is subject to wide variation. It is always less than the sum of the peak flows from all of the tributary streams because, on account of the rate and direction of storm travel and the variation in distance of the watersheds of the tributary streams from the point of concentration, the separate peak flows do not all reach the point of concentration at the same time, and also because the peak flows are reduced by channel storage before reaching the point of concentration.

The summer floods occur during the period April to August and are most pronounced on the larger streams whose headwaters are in the high Sierra Nevada. They are caused by the rapid melting of the snow which has accumulated during the winter in the mountains at the higher elevations and are sometimes augmented by spring rains. Summer floods are usually of much greater duration than winter floods and may continue for a period of a month or more. They have no sharp peaks and the maximum flows are not as large as the maximum or peak flows of winter floods. Since the summer floods are of considerable duration, however, the total volume of run-off during such floods may be much greater than in the largest winter floods. Also, since the flows extend over a relatively long period, the flows at points of concentration on the valley floor may more nearly approach the sum of the maximum flows in the tributary streams than they do in winter floods. However, there is practically no run-off from the streams from the lower mountains and the valley floor in the summer and the maximum summer flood flows at the points of concentration on the valley floor are smaller than the peak flows during winter floods.



PROBABLE FREQUENCY OF FLOOD FLOWS AT FOOTHILL GAGING STATIONS ON MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

Flood Flows at Foothill Gaging Stations—In estimating the probable amounts of flood discharge at a gaging station for specified frequencies, the total recorded volumes of flood flow during periods of one, two, three, four or more days were tabulated in descending order of magnitude, thus giving the number of times of occurrence, or frequency, of a flood of a certain duration and magnitude during the period of stream flow record. The probable number of times that each volume of flow would have occurred in 100 years was obtained by multiplying the order of the frequency by 100 divided by the number of years in the period of record. These values were plotted on logarithmic paper with the vertical scale representing the frequency with which the volumes of flow would be exceeded in 100 years on the average and the horizontal scale the volume of the flow. Curves drawn to conform to the trend of these plotted points were extended to give the volumes of flood flow which may be expected to be exceeded once in 250 years on an average. Curves for winter floods drawn in this manner are shown for each of the stations studied on Plate LXXIV, "Probable Frequency of Flood Flows at Foothill Gaging Stations on Major Streams of San Joaquin River Basin." In selecting the data for the development of these curves, a flood was considered to be a winter or rain water flood, even if it occurred in April, if the increase in flow over that in preceding days appeared to have been caused by rainfall or by rainfall and melting snow caused by the rain. Similar curves were drawn for summer floods of 1, 3, 6, 12, 24 and 36 days duration but are not shown in this report. In selecting the data for the development of these latter curves, a flood was considered to be a summer or snow water flood, even as early as April, if it appeared to have been caused primarily by melting snow and even if some slight increases of flow in May were due to spring rains. The total run-offs and mean flows during both summer and winter floods, which it is estimated may occur with certain frequencies at the foothill gaging stations on the major streams of the San Joaquin River Basin, were obtained from the frequency curves and are shown in Tables 187 to 199, inclusive. Table 200 gives the probable maximum mean daily flows which may be exceeded with certain frequencies at the same foothill gaging stations. "Mean daily flow" is the uniform flow throughout a calendar day which would give a total run-off equal to that which actually occurred with variable rates of flow. For the Calaveras River, total run-offs and mean flows are given for periods of 24, 48 and 72 hours. These hour periods are those including the maximum run-off without regard to calendar day limits.

TABLE 187

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF KERN RIVER NEAR BAKERSFIELD

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	20,400	10,300	32,900	16,600	43,400	21,900	55,100	27,800	71,000	35,800
2	33,300	8,400	52,000	13,100	68,800	17,350	87,300	22,000	111,000	28,000
3	43,200	7,270	66,100	11,100	86,900	14,600	109,100	18,330	135,900	22,830
4	51,400	6,480	78,000	9,820	101,800	12,820	126,500	15,950	157,700	19,880
6	64,700	5,430	97,200	8,170	124,600	10,470	152,700	12,830	191,400	16,080
8	75,600	4,760	113,700	7,160	143,400	9,040	174,500	11,000	220,200	13,880
10	84,900	4,280	126,900	6,400	158,700	8,000	194,400	9,800	242,000	12,200
					Summer Floods					
1	12,500	6,300	16,400	8,300	19,400	9,800	23,000	11,600	28,200	14,200
3	35,500	6,000	46,800	7,900	55,700	9,400	65,500	11,000	80,300	13,500
6	67,600	5,700	88,100	7,400	104,300	8,800	123,000	10,300	148,800	12,500
12	126,000	5,300	163,600	6,900	194,400	8,200	229,900	9,700	278,500	11,700
24	234,100	4,900	309,400	6,500	365,000	7,700	428,400	9,000	519,700	10,900
36	335,200	4,700	438,400	6,100	519,700	7,300	612,900	8,600	743,800	10,400

TABLE 188

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF TULE RIVER NEAR PORTERVILLE, NOT INCLUDING SOUTH FORK

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	10,200	5,150	12,500	6,300	13,900	7,000	15,200	7,650	16,700	8,400
2	16,900	4,250	20,200	5,100	22,400	5,650	24,200	6,100	26,000	6,550
3	20,200	3,400	25,200	4,230	28,000	4,700	30,300	5,100	32,500	5,470
4	23,400	2,950	29,000	3,650	32,300	4,080	35,500	4,480	38,300	4,820
6	28,400	2,380	35,100	2,950	39,500	3,320	43,200	3,630	46,800	3,930
8	32,500	2,050	40,500	2,550	45,600	2,880	49,600	3,120	53,400	3,360
10	36,300	1,830	45,200	2,280	50,800	2,560	55,300	2,790	59,300	2,990
					Summer Floods					
1	2,500	1,250	3,900	1,960	5,100	2,580	6,500	3,270	8,500	4,290
3	6,400	1,080	10,100	1,690	13,200	2,210	16,500	2,780	21,400	3,600
6	11,400	950	17,400	1,460	22,300	1,880	28,200	2,370	36,300	3,050
12	19,800	830	29,400	1,230	37,900	1,590	47,400	1,990	60,700	2,550
24	35,200	740	51,600	1,080	65,500	1,380	81,100	1,700	100,800	2,120
36	49,600	690	71,400	1,000	89,700	1,260	110,100	1,540	137,300	1,920

NOTE.—The flows in Table 188 are for the main stream only and do not include those for the South Fork. The sizes of flood for various frequencies for the combined flows of the main river and the South Fork (as measured at Success), below their confluence, would be about one-third larger than those shown in the table.

TABLE 189

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF KAWEAH RIVER AT THREE RIVERS

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	19,100	9,650	23,800	12,000	27,200	13,700	30,100	15,200	33,900	17,100
2	29,600	7,450	36,500	9,200	41,500	10,450	45,400	11,450	50,200	12,650
3	35,700	6,000	44,000	7,400	49,600	8,330	54,700	9,200	60,500	10,170
4	40,900	5,150	49,600	6,250	56,100	7,080	61,500	7,750	67,800	8,550
6	48,800	4,100	59,700	5,020	67,000	5,630	73,400	6,170	80,900	6,800
8	56,500	3,560	69,200	4,360	77,400	4,880	84,900	5,350	93,200	5,880
10	64,100	3,230	77,600	3,910	86,300	4,350	94,200	4,750	103,100	5,200
					Summer Floods					
1	8,700	4,400	10,700	5,400	12,500	6,280	14,300	7,200	16,900	8,500
3	24,400	4,100	30,100	5,070	34,900	5,870	40,100	6,730	47,200	7,930
6	45,800	3,850	56,900	4,780	65,900	5,530	76,000	6,380	89,700	7,530
12	85,500	3,590	106,100	4,460	122,600	5,150	140,800	5,920	165,600	6,960
24	152,700	3,210	190,400	4,000	220,200	4,620	251,900	5,290	297,500	6,250
36	214,200	3,000	267,800	3,750	309,400	4,330	355,000	4,970	414,600	5,810

TABLE 190

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF KINGS RIVER AT PIEDRA

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	51,200	25,800	67,400	34,000	80,300	40,500	92,200	46,500	105,700	53,300
2	76,400	19,250	100,200	25,250	118,000	29,750	134,900	34,000	152,700	38,500
3	96,200	16,170	126,900	21,330	148,800	25,000	169,600	28,500	190,400	32,000
4	112,100	14,120	146,800	18,500	171,600	21,620	194,400	24,500	216,200	27,250
6	135,900	11,420	177,500	14,920	204,300	17,170	231,100	19,420	255,900	21,500
8	152,700	9,620	196,400	12,380	226,100	14,250	255,900	16,120	281,700	17,750
10	168,600	8,500	213,200	10,750	245,000	12,350	275,700	13,900	302,500	15,250
					Summer Floods					
1	37,700	19,000	44,800	22,600	50,200	25,300	55,900	28,200	63,900	32,200
3	109,700	18,400	128,900	21,700	143,400	24,100	158,300	26,600	178,500	30,000
6	208,300	17,500	244,000	20,500	271,700	22,800	298,500	25,100	337,200	28,300
12	382,800	16,100	450,300	18,900	499,800	21,000	551,400	23,200	622,800	26,200
24	674,400	14,200	793,400	16,700	890,600	18,700	985,800	20,700	1,118,700	23,500
36	940,200	13,200	1,110,800	15,600	1,235,700	17,300	1,374,600	19,200	1,563,000	21,900

TABLE 191

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF SAN JOAQUIN RIVER NEAR FRIANT

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	52,800	26,600	64,900	32,700	73,200	36,900	81,300	41,000	91,200	46,000
2	84,700	21,350	104,100	26,250	118,000	29,750	130,300	32,850	145,800	36,750
3	107,100	18,000	131,900	22,170	148,200	24,900	163,600	27,500	182,500	30,670
4	123,000	15,500	150,700	19,000	168,000	21,180	186,400	23,500	206,300	26,000
6	146,800	12,330	178,500	15,000	200,300	16,830	222,200	18,670	244,000	20,500
8	169,600	10,690	203,300	12,810	226,100	14,250	249,900	15,750	275,700	17,380
10	185,500	9,350	222,200	11,200	246,000	12,400	271,700	13,700	301,500	15,200
					Summer Floods					
1	41,900	21,100	50,000	25,200	55,300	27,900	60,900	30,700	67,400	34,000
3	117,000	19,700	138,400	23,300	152,700	25,700	168,200	28,300	187,400	31,500
6	222,200	18,700	261,800	22,000	287,600	24,200	315,400	26,500	343,100	28,800
12	402,700	16,900	478,000	20,100	521,700	21,900	559,300	23,500	612,900	25,800
24	714,100	15,000	839,000	17,600	912,400	19,200	973,900	20,500	1,061,200	22,300
36	983,800	13,800	1,162,300	16,300	1,259,500	17,600	1,348,800	18,900	1,457,900	20,400

TABLE 192

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF WINTER FLOOD FLOWS OF FRESNO RIVER NEAR KNOWLES

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
1	6,980	3,500	9,120	4,600	10,900	5,500	12,600	6,350	14,700	7,100
2	10,100	2,550	13,100	3,300	15,500	3,900	17,900	4,500	20,600	5,200
3	12,100	2,030	15,700	2,630	18,400	3,100	21,200	3,570	24,400	4,100
4	13,700	1,720	17,700	2,220	21,000	2,650	24,000	3,020	27,800	3,500
6	16,500	1,380	21,200	1,780	25,200	2,120	28,800	2,420	33,300	2,800
8	18,800	1,190	24,200	1,520	28,600	1,800	32,700	2,060	37,900	2,390
10	20,800	1,050	26,800	1,350	31,700	1,600	36,100	1,820	41,500	2,090

TABLE 193

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF MERCED RIVER AT MERCED FALLS

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	52,200	26,300	66,100	33,300	76,800	38,700	87,300	44,000	100,400	50,600
2	84,300	21,200	111,100	28,000	129,900	32,800	149,800	37,800	175,500	44,200
3	111,100	18,700	149,800	25,200	179,900	30,200	208,300	35,000	246,000	41,300
4	130,900	16,500	178,500	22,500	214,200	27,000	253,900	32,000	303,500	38,200
6	159,100	13,400	220,200	18,500	269,800	22,700	317,400	26,700	380,800	32,000
8	185,500	11,700	257,900	16,200	317,400	20,000	374,900	23,600	450,300	28,400
10	210,300	10,600	289,600	14,600	361,000	18,200	422,500	21,300	503,800	25,400
					Summer Floods					
1	22,000	11,100	26,400	13,300	29,800	15,000	33,100	16,700	37,300	18,800
3	62,100	10,400	74,200	12,500	83,100	14,000	92,800	15,600	104,700	17,600
6	116,600	9,800	138,800	11,700	156,700	13,200	175,500	14,800	198,500	16,700
12	218,200	9,200	263,800	11,100	295,500	12,400	331,200	13,900	370,900	15,600
24	392,700	8,200	476,000	10,000	533,600	11,200	593,100	12,500	666,500	14,000
36	535,500	7,500	652,600	9,100	729,900	10,200	809,300	11,300	910,400	12,700

TABLE 194

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF TUOLUMNE RIVER NEAR LA GRANGE

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	62,300	31,400	78,500	39,600	92,200	46,500	106,100	53,500	125,400	63,200
2	108,700	27,400	140,000	35,300	164,200	41,400	186,800	47,100	218,200	55,000
3	144,400	24,300	186,400	31,300	222,200	37,300	251,900	42,300	291,600	49,000
4	173,600	21,900	225,100	28,400	265,800	33,500	305,500	38,500	353,100	44,500
6	217,200	18,200	283,600	23,800	333,200	28,000	384,800	32,300	440,300	37,000
8	253,900	16,000	333,200	21,000	392,700	24,800	452,200	28,500	515,700	32,500
10	285,600.	14,400	376,900	19,000	442,300	22,300	509,800	25,700	581,200	29,300
					Summer Floods					
1	35,500	17,900	40,300	20,300	43,800	22,100	47,600	24,000	52,000	26,200
3	101,200	17,000	116,000	19,500	126,000	21,200	135,900	22,800	148,800	25,000
6	194,400	16,300	222,200	18,700	242,000	20,300	261,800	22,000	285,600	24,000
12	355,000	14,900	408,600	17,200	444,300	18,700	482,000	20,200	531,600	22,300
24	656,500	13,800	749,800	15,800	825,100	17,300	890,600	18,700	779,900	20,500
36	912,400	12,800	1,041,300	14,600	1,140,500	16,000	1,229,800	17,200	1,348,800	18,900

TABLE 195

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF STANISLAUS RIVER AT KNIGHTS FERRY

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
					Winter Floods					
1	71,800	36,200	99,200	50,000	121,000	61,000	142,800	72,000	170,600	86,000
2	115,000	29,000	156,700	39,500	188,400	47,500	222,200	56,000	253,900	64,000
3	142,800	24,000	192,400	32,300	230,100	38,700	269,800	45,300	311,400	52,300
4	166,600	21,000	224,100	28,200	265,800	33,500	311,400	39,200	359,000	45,200
6	206,300	17,300	277,700	23,300	331,200	27,800	382,800	32,200	440,300	37,000
8	238,000	15,000	319,300	20,100	380,800	24,000	440,300	27,800	501,800	31,600
10	263,800	13,300	351,100	17,700	416,500	21,000	480,000	24,200	545,500	27,500
					Summer Floods					
1	25,200	12,700	30,500	15,400	34,900	17,600	39,300	19,800	44,400	22,400
3	72,000	12,100	86,900	14,600	97,800	16,400	109,100	18,300	123,000	20,700
6	137,300	11,500	164,600	13,800	183,500	15,400	204,300	17,200	226,100	19,000
12	251,900	10,600	301,500	12,700	335,200	14,100	370,900	15,600	412,600	17,300
24	456,200	9,600	541,500	11,400	603,000	12,700	658,500	13,800	733,900	15,400
36	632,700	8,900	743,800	10,400	821,200	11,500	892,600	12,500	977,700	13,700

TABLE 196

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF WINTER FLOOD FLOWS OF CALAVERAS RIVER AT JENNY LIND

Number of hours of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
24	78,100	39,400	114,100	57,500	144,800	73,000	174,500	88,000	212,200	107,000
48	119,000	30,000	173,600	43,800	220,200	55,500	265,800	67,000	321,300	81,000
72	134,900	22,700	196,400	33,000	246,000	41,300	299,500	50,300	359,000	60,300

TABLE 197

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF FLOOD FLOWS OF MOKELUMNE RIVER NEAR CLEMENTS

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
Winter Floods										
1	35,300	17,800	47,200	23,800	57,100	28,800	66,800	33,700	78,300	39,500
2	59,300	15,000	80,100	20,200	96,800	24,400	114,100	28,800	134,900	34,000
3	78,900	13,300	107,900	18,100	129,900	20,800	153,700	25,800	183,500	30,800
4	92,600	11,700	126,900	16,000	154,700	19,500	183,500	23,100	220,200	27,800
6	115,000	9,700	159,700	13,400	194,400	16,300	230,100	19,300	275,700	23,200
8	133,900	8,400	183,500	11,600	222,200	14,000	261,800	16,500	313,400	19,800
10	149,800	7,600	202,300	10,200	244,000	12,300	285,600	14,400	341,200	17,200
Summer Floods										
1	18,500	9,400	22,400	11,300	26,000	13,100	29,400	14,800	34,300	17,300
3	51,800	8,700	62,100	10,400	71,200	12,000	79,900	13,400	91,600	15,400
6	95,800	8,100	117,000	9,800	132,900	11,200	149,800	12,600	174,500	14,700
12	176,900	7,400	218,200	9,200	251,900	10,600	283,600	11,900	331,200	13,900
24	315,400	6,600	384,800	8,100	442,300	9,300	503,800	10,600	591,100	12,400
36	422,500	5,900	511,700	7,200	583,100	8,200	660,500	9,300	769,600	10,800

TABLE 198

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF WINTER FLOOD FLOWS OF DRY CREEK NEAR IONE

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
1	11,900	6,000	15,100	7,600	17,500	8,800	19,400	9,800	21,800	11,000
2	18,000	4,550	23,000	5,800	27,000	6,800	30,000	7,550	33,900	8,550
3	23,400	3,930	30,500	5,130	35,700	6,000	40,300	6,770	45,600	7,670
4	28,600	3,600	36,900	4,650	43,400	5,480	48,800	6,150	55,100	6,950
6	32,900	2,770	42,800	3,600	50,200	4,220	56,700	4,770	64,500	5,420
8	36,900	2,320	48,000	3,020	55,900	3,520	63,300	3,990	73,000	4,600
10	40,300	2,030	52,200	2,630	60,700	3,060	68,200	3,440	78,300	3,950

TABLE 199

PROBABLE SIZES AND FREQUENCIES OF OCCURRENCE OF WINTER FLOOD FLOWS OF COSUMNES RIVER AT MICHIGAN BAR

Number of days of flow	Flood which may be exceeded on average of									
	Once in 10 years		Once in 25 years		Once in 50 years		Once in 100 years		Once in 250 years	
	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet	Total run-off, in acre-feet	Mean flow, in second-feet
1	40,300	20,300	50,800	25,600	58,900	29,700	65,900	33,200	74,200	37,400
2	67,000	16,900	84,900	21,400	99,200	25,000	112,500	28,400	126,900	32,000
3	84,700	14,200	109,500	18,400	127,300	21,400	144,400	24,300	163,200	27,400
4	98,800	12,400	127,900	16,100	149,200	18,800	168,600	21,200	191,400	24,100
6	119,400	10,000	153,700	12,900	178,900	15,000	204,300	17,200	232,100	19,500
8	137,900	8,700	177,500	11,200	206,300	13,000	236,000	14,900	267,800	16,900
10	154,700	7,800	199,300	10,000	232,100	11,700	263,800	13,300	297,500	15,000

TABLE 200

PROBABLE FREQUENCY OF MAXIMUM MEAN DAILY FLOOD FLOWS AT FOOTHILL GAGING STATIONS ON MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

Stream aud location of gage	Probable maximum mean daily flow[1], in second-feet, exceeded on average of once in				
	10 years	25 years	50 years	100 years	250 years
Kern River near Bakersfield	10,300	16,600	21,900	27,800	35,800
Tule River near Porterville	5,150	6,300	7,000	7,650	8,400
Kaweah River at Three Rivers	9,650	12,000	13,700	15,200	17,100
Kings River at Piedra	25,800	34,000	40,500	46,500	53,300
San Joaquin River near Friant	26,600	32,700	36,900	41,000	46,000
Fresno River near Knowles	3,500	4,600	5,500	6,350	7,400
Merced River at Merced Falls	26,300	33,300	38,700	44,000	50,600
Tuolumne River near La Grange	31,400	39,600	46,500	53,500	63,200
Stanislaus River at Knights Ferry	36,200	50,000	61,000	72,000	86,000
Calaveras River at Jenny Lind	[2]39,400	[2]57,500	[2]73,000	[2]88,000	[2]107,000
Mokelumne River near Clements	17,800	23,800	28,800	33,700	39,500
Dry Creek near Ione	6,000	7,600	8,800	9,800	11,000
Cosumnes River at Michigan Bar	20,300	25,600	29,700	33,200	37,400

[1] All flows are for winter floods. Maximum mean daily flows during summer floods are smaller than those during winter floods in all cases.
[2] Flows are mean for 24 hour period of maximum run-off.

Winter Flood Flows at Selected Points of Concentration on Lower San Joaquin Valley Floor—Knowledge of the amounts of flood flow at points within the area subject to inundation is essential to the design of works for the protection from floods of the valley lands affected. Studies were made, therefore, to estimate the winter flood flows and the probable frequency of their occurrence at several points of concentration on the San Joaquin Valley floor. Winter floods were chosen for this study since the concentrated flows during maximum floods of this type are larger than the concentrated summer flood flows and works for full protection would therefore be designed for winter flood flows. A study was also made of flows during the 1906 summer flood, which is the largest of record, and the amounts of flow are given later in this chapter in connection with plans for protection against such a flood.

Flows in the San Joaquin River at points on the valley floor are made up of the combined flows of the larger tributary streams, the flows of which are measured at points near the edge of the valley floor; the flows from smaller mountain and foothill streams for which there are no records of flow; run-offs from valley floor areas, which are also unmeasured. The flow of the main San Joaquin River is measured at two points on the valley floor, one just below the mouth of the Merced River near Newman, and the other just below the mouth of the Stanislaus River near Vernalis. Flows at these stations include those which are measured at the line of the valley floor, and those which are not measured in the tributary streams. Records of flows at the Newman station have been obtained by the United States Geological Survey throughout the year since April, 1912, but no records of the flows at the Vernalis station have been obtained during the winter months and records at this station are therefore of no use in studies of winter flood flows.

The valley floor points at which flood flows were estimated, the total area of the mountain drainage basin tributary to each point, and the division of this total area into areas having measured run-off and areas having no measured run-off except for the measurements taken at the Newman and Vernalis stations, are shown in Table 201.

TABLE 201

CLASSIFICATION OF AREAS OF MOUNTAIN DRAINAGE BASINS TRIBUTARY TO SELECTED POINTS OF CONCENTRATION ON LOWER SAN JOAQUIN VALLEY FLOOR

Point of concentration	Mountain drainage areas				
	Total in square miles[1]	With measured run-off		Without measured run-off	
		In square miles	In per cent of total	In square miles	In per cent of total
San Joaquin River below confluence of San Joaquin and Merced rivers	5,108	[2]2,955	58	2,153	42
San Joaquin River below confluence of San Joaquin and Tuolumne rivers	6,915	4,498	65	2,417	35
San Joaquin River below confluence of San Joaquin and Stanislaus rivers	8,014	5,481	68	2,533	32
San Joaquin and Sacramento rivers at confluence	31,793	25,722	81	6,071	19

[1] Areas south of San Joaquin River not included in total areas. Areas are from Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, 1923.
[2] Includes Fresno River.

Flood flows at each selected point of concentration may be estimated by combining measured flows at the gaging stations on the major streams above the point with estimated flows from the tributary areas which have no measured run-offs, with proper allowances for time of travel of the flows and for channel storage. The areas without measured run-off are large, however, as shown by Table 201, and it is difficult to estimate flood discharges from these areas. They can not be estimated by comparison with the measured flows of the major streams because there is little similarity in the drainage basins of adjacent unmeasured and measured streams in position, elevation, and shape of watershed. Therefore, no attempt was made in these studies of flood concentration to estimate flood flows from areas having no measured run-off. Flows at the selected points of concentration were estimated instead from measured flows at the foothill gaging stations and at the Newman gaging station. The method used for each selected point is briefly described in the following paragraphs. The period used in these studies was 1896 to 1929 and since stream flow records are not available for all of the major tributary streams for the entire period, it was necessary to estimate flows for some years for each stream, except the Tuolumne River, by comparison with the flow records of the Tuolumne, Kings and American rivers. The estimated flood concentrations are necessarily not exact and must be so considered.

The amounts of flood flow in the San Joaquin River below its confluence with the Merced River, for the period since 1912, were obtained from the published records for the Newman gaging station. Amounts prior to that date were estimated from the relation of flows at the Newman gaging station to the combined mean daily flows of the Merced River at Merced Falls or Exchequer and those of the San Joaquin River at Friant or Herndon, with the proper allowances for the time of concentration, channel storage, and the relation of peak to mean daily flow. Use was also made of a detailed analysis made some years ago by the State Division of Engineering and Irrigation of concentrations and the relation of peak to mean daily flow during the flood of January, 1911.

The amount of the concentrated flood flow of the San Joaquin River below its confluence with the Tuolumne River was estimated by combining the flood flow of the San Joaquin River below the mouth of the Merced River with the flow of the Tuolumne River at the La Grange gaging station, with corrections for the relative time of flood travel from each of these latter points to the point of concentration below the mouth of the Tuolumne River, and for channel storage. In a similar manner, the concentrated flood flow of the San Joaquin River below its confluence with the Stanislaus River was estimated by combining the flood flow in the San Joaquin River below the mouth of the Tuolumne River with the flow in the Stanislaus River at Knights Ferry, with corrections for time of flood travel and channel storage.

Another point at which amounts of concentrated flood flows were estimated is the confluence of the San Joaquin and Sacramento rivers. In estimating the flow at this point, the concentrated flow in the San Joaquin River below the mouth of the Stanislaus River was combined with the flow from the Sacramento Valley as estimated during the preparation of a report* on the flood concentration in the valley, and the flows into the San Joaquin Delta from the Cosumnes, Mokelumne and Calaveras rivers. Allowance was made in each case for the time of travel from the point at which each of these flows was estimated to the confluence of the main rivers, and for channel storage.

Flood flows at the selected points of concentration, estimated as above described, were then analyzed to estimate the probable sizes of floods at the same points which may be expected to be exceeded at various intervals of time on the average. The method used was the same as that used for the same purpose for the foothill gaging stations. The curves so derived are shown on Plate LXXV, "Probable Frequency of Flood Flows at Points of Concentration on San Joaquin Valley Floor," and are in each case the right-hand curve for each station, designated "without reservoir control." Table 202 shows the estimated maximum flows that would occur with certain frequencies at the points of concentration.

TABLE 202

PROBABLE FREQUENCIES OF WINTER FLOOD FLOWS AT SELECTED POINTS OF CONCENTRATION ON LOWER SAN JOAQUIN VALLEY FLOOR

Without Reservoir Control

Stream and point of concentration	Probable maximum mean daily flow, in second-feet, exceeded on average of once in				
	10 years	25 years	50 years	100 years	250 years
San Joaquin River below confluence of San Joaquin and Merced rivers	42,000	53,000	62,000	69,500	79,500
San Joaquin River below confluence of San Joaquin and Tuolumne rivers	64,000	80,000	92,000	103,000	117,000
San Joaquin River below confluence of San Joaquin and Stanislaus rivers	86,000	104,000	118,000	133,000	154,000
San Joaquin and Sacramento rivers at confluence	490,000	592,000	680,000	780,000	925,000

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

31—80997

Methods of Flood Control.

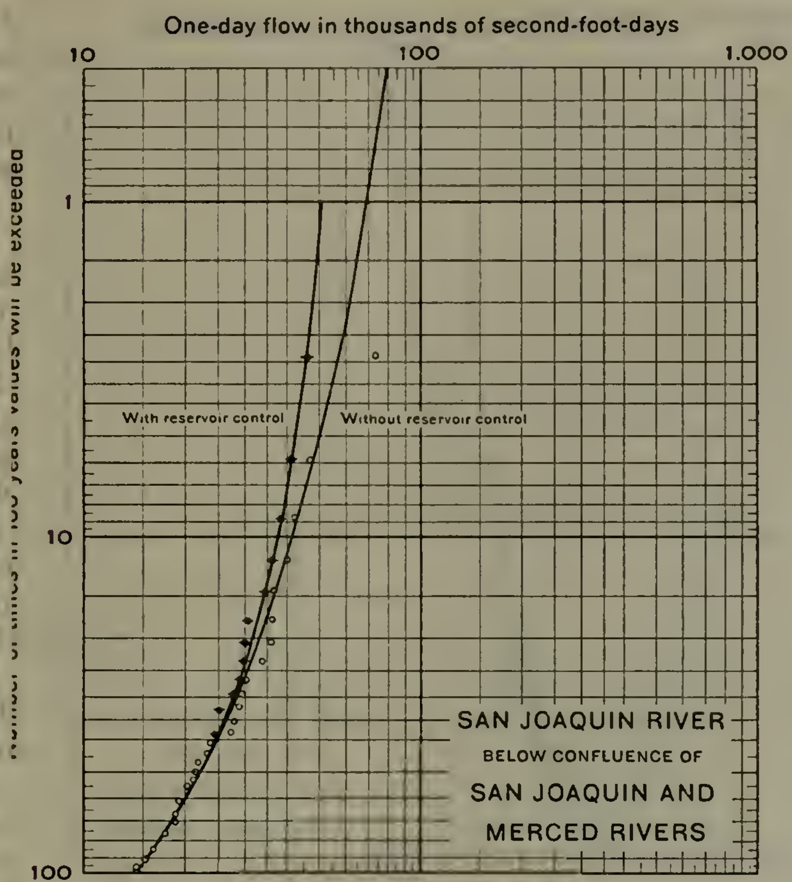
There are two general methods for controlling floods. One method is to convey the flood waters of the streams undiminished in volume past the area subject to overflow by means of leveed channels constructed either along the natural waterways, or, where the natural waterways are inadequate in capacity, through leveed by-passes. The other method is to reduce the flood flows by retention in surface reservoirs of flows in excess of the capacity of the natural waterways and to later release the water from these reservoirs at a rate which does not exceed the natural channel capacity.

The first method is the more common and is that used on the Mississippi River and in the Sacramento Valley. The only examples of the second method in California are the Los Angeles County flood control project and the city of Stockton project on the Calaveras River. The first method is usually the less costly. The second method, where the reservoirs are used for flood control purposes alone, is justified only where high property values make flood channels costly or undesirable and where close settlement and high values in the territory protected permit greater expenditures for this protection. In most instances, however, even with floods controlled by reservoirs, some leveed channels are required, so that control by this method generally resolves itself into a plan of reservoir control combined with levee systems. Sometimes this method of flood control is combined with the spreading of flood waters over absorptive areas to introduce these waters into the underground basin for storage. Where flood control by reservoirs can be combined successfully with conservation, the cost chargeable to flood control is thereby reduced.

Plans for Flood Control with Flows Uncontrolled by Reservoirs.

As previously stated, no comprehensive plan for the protection of overflow lands or for the control of floods in the San Joaquin Valley has been adopted. However, following the formulation of a general flood control plan for the Sacramento Valley, attention was turned to the preparation of a similar plan for the San Joaquin Valley and the California Debris Commission and the Department of Engineering of California, cooperating, made surveys and formulated a tentative flood control plan for the lower San Joaquin Valley and the San Joaquin Delta.

Upper San Joaquin Valley South of San Joaquin River—In the San Joaquin Valley south of the San Joaquin River, a large part of any inundation by floods would occur in the beds of Buena Vista and Tulare lakes. It is anticipated that during large floods Buena Vista Lake will be flooded, and the lands are reserved for this purpose. Water in excess of the amount which will flood the reservoir lands will flow northward toward Tulare Lake. Tulare Lake lands will also be flooded by water collecting in the bed of the lake and it is, therefore, the total volume of run-off into the lake that is important as a flood menace, and not the peak or mean daily stream flow. Waters from the Kern, Tule, Kaweah and Kings rivers now reach the lake bed. The area flooded is dependent upon the amounts of excess water in any one or series of years since physical conditions are such that the flood waters entering Tulare Lake, the lowest point in which is elevation 179 feet,



PROBABLE FREQUENCY
OF FLOOD FLOWS
AT
POINTS OF CONCENTRATION
ON
SAN JOAQUIN VALLEY FLOOR
WITH AND WITHOUT RESERVOIR CONTROL

Methods of Flood Control.

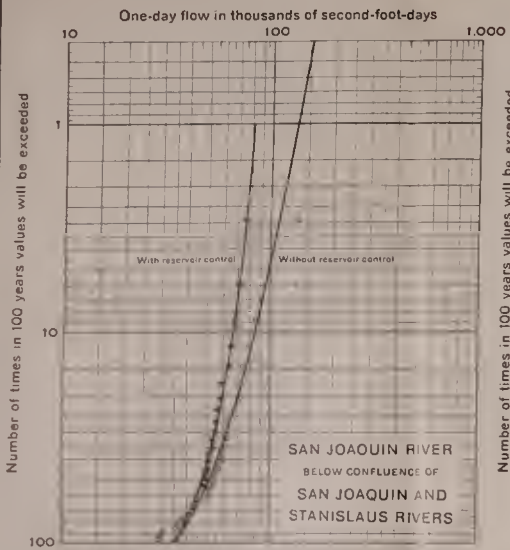
There are two general methods for controlling floods. One method is to convey the flood waters of the streams undiminished in volume past the area subject to overflow by means of leveed channels constructed either along the natural waterways, or, where the natural waterways are inadequate in capacity, through leveed by-passes. The other method is to reduce the flood flows by retention in surface reservoirs of flows in excess of the capacity of the natural waterways and to later release the water from these reservoirs at a rate which does not exceed the natural channel capacity.

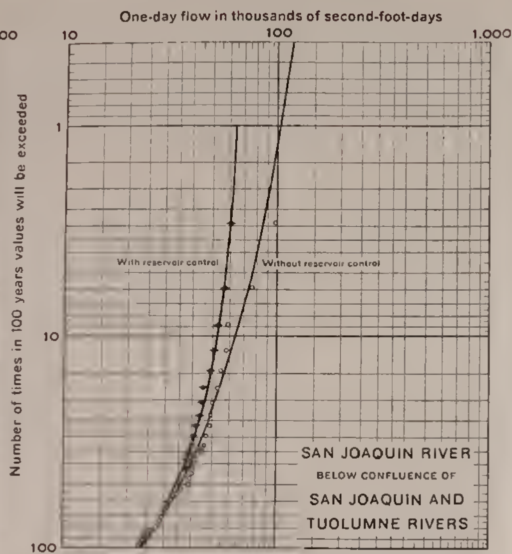
The first method is the more common and is that used on the Mississippi River and in the Sacramento Valley. The only examples of the second method in California are the Los Angeles County flood control project and the city of Stockton project on the Calaveras River. The first method is usually the less costly. The second method, where the reservoirs are used for flood control purposes alone, is justified only where high property values make flood channels costly or undesirable and where close settlement and high values in the territory protected permit greater expenditures for this protection. In most instances, however, even with floods controlled by reservoirs, some leveed channels are required, so that control by this method generally resolves itself into a plan of reservoir control combined with levee systems. Sometimes this method of flood control is combined with the spreading of flood waters over absorptive areas to introduce these waters into the underground basin for storage. Where flood control by reservoirs can be combined successfully with conservation, the cost chargeable to flood control is thereby reduced.

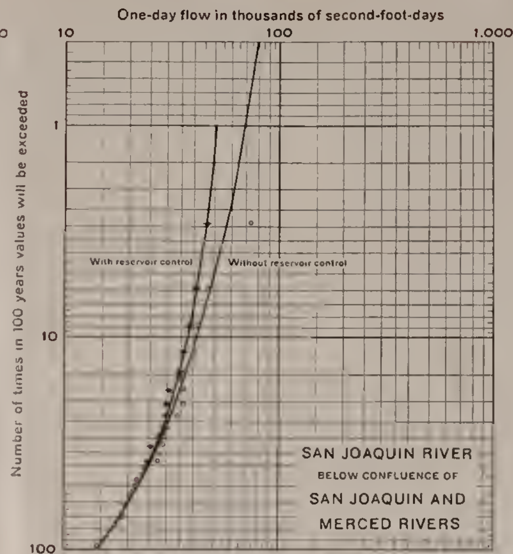
Plans for Flood Control with Flows Uncontrolled by Reservoirs.

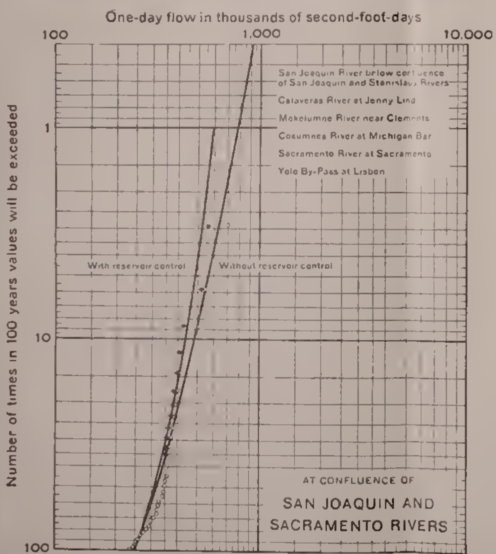
As previously stated, no comprehensive plan for the protection of overflow lands or for the control of floods in the San Joaquin Valley has been adopted. However, following the formulation of a general flood control plan for the Sacramento Valley, attention was turned to the preparation of a similar plan for the San Joaquin Valley and the California Debris Commission and the Department of Engineering of California, cooperating, made surveys and formulated a tentative flood control plan for the lower San Joaquin Valley and the San Joaquin Delta.

Upper San Joaquin Valley South of San Joaquin River—In the San Joaquin Valley south of the San Joaquin River, a large part of any inundation by floods would occur in the beds of Buena Vista and Tulare lakes. It is anticipated that during large floods Buena Vista Lake will be flooded, and the lands are reserved for this purpose. Water in excess of the amount which will flood the reservoir lands will flow northward toward Tulare Lake. Tulare Lake lands will also be flooded by water collecting in the bed of the lake and it is, therefore, the total volume of run-off into the lake that is important as a flood menace, and not the peak or mean daily stream flow. Waters from the Kern, Tule, Kaweah and Kings rivers now reach the lake bed. The area flooded is dependent upon the amounts of excess water in any one or series of years since physical conditions are such that the flood waters entering Tulare Lake, the lowest point in which is elevation 179 feet,









FLOWS AT EDGE OF VALLEY FLOOR
WITH RESERVOIR CONTROL

Exceeded once in 100 years on the average

SAN JOAQUIN RIVER BASIN

Kings River at Piedra	15,000 second-feet
San Joaquin River near Friant	15,000 second-feet
Merced River at Exchequer	25,000 second-feet
Tuolumne River near La Grange	15,000 second-feet
Stanislaus River at Knights Ferry	15 000 second-feet
Calaveras River at Jenny Lind	25,000 second-feet
Mokelumne River near Clements	10,000 second-feet
Dry Creek near Ione	5,000 second-feet
Cosumnes River at Michigan Bar	15,000 second-feet

SACRAMENTO RIVER BASIN

Sacramento River at Red Bluff	125,000 second-feet
Feather River at Oroville	100,000 second-feet
Yuba River at Smartsville	70,000 second-feet
Bear River at Van Trent	20,000 second-feet
American River at Fairoaks	100 000 second feet

PROBABLE FREQUENCY OF FLOOD FLOWS AT POINTS OF CONCENTRATION ON SAN JOAQUIN VALLEY FLOOR

WITH AND WITHOUT RESERVOIR CONTROL

80997

must raise the lake surface to an elevation of 205 to 210 feet before they can escape northward into Fresno Slough and the San Joaquin River. Some of the levees in the lake bed may withstand such elevations but many are constructed to an elevation of not over 195 feet and many thousands of acres of land would be flooded by a lake level of 210 feet.

Under present plans for the reclamation of Tulare Lake lands, the north half of Township 22 South, Range 20 East, M.D.B. and M., is reserved for the storage of surplus waters, and for major floods, the south half of the township and the land south of the township to elevations of 192 to 195 feet would also be used. This gives storage capacities of 260,000 to 350,000 acre-feet before inundating additional lands. These storage capacities are insufficient to store all of the water which would reach the lake under present conditions of development in the tributary drainage area.

To relieve Tulare Lake of waters in excess of the capacity of the storage reservoir in the lake bed, two plans were proposed several years ago by A. D. Schindler, engineer for landowners in the lake bed. Under both plans, the surplus waters of Kings River would be diverted directly to Fresno Slough and the San Joaquin River. Under the first plan, the surplus waters from the Kern River area would be by-passed through a canal around the west side of the lake from a point near Harts Station to Summit Lake, and thence down Fresno Slough. Surplus water from the Kaweah and Tule rivers would be diverted southward through unimproved territory, combined with the Kern River water at Harts Station, and diverted northward around the lake in the by-pass canal. The capacity of the canal from Harts Station to Summit Lake would be 8500 second-feet with an emergency capacity of about 10,000 second-feet. The cost of this canal and one from the Kaweah and Tule rivers to Harts Station, together with diversion works on these rivers, was estimated by A. D. Schindler in 1917 to be about $2,200,000.

Under the second plan proposed, all excess waters which would reach Tulare Lake would be discharged into the reservoir in the lake bed and the reservoir would be vented northward by means of a deep cut through Summit Lake Ridge to Fresno Slough. The bottom of this cut or canal would be as low as the bottom of the lake and it would have a capacity of about 3200 second-feet. It was estimated by A. D. Schindler that this canal would have controlled flood waters to such an extent that no flooding would have occurred on lands surrounding the lake reservoir under such extreme conditions as existed in 1906 and 1916. The cost of this canal and appurtenant works was estimated by A. D. Schindler in 1917 to be $1,060,000. This estimate was revised to $1,200,000 by S. T. Harding in a report to the Tulare Lake Water Storage District in 1924.

Upper and Lower San Joaquin Valleys—Herndon to Mouth of Merced River—In the section of the valley from Herndon to the mouth of the Merced River, the flood plain is several miles in width and it is believed that in this section protection against both winter and summer floods could be provided, since only a small portion of the lands subject to inundation would be required for overflow channels. Several preliminary plans for protecting these lands from uncontrolled flows were laid out and preliminary estimates of cost were made some years ago by the State Division of Engineering and Irrigation. Two of these plans have recently been revised by the Division of Water Resources and preliminary estimates made of the costs of constructing the works.

Under one of these plans, a by-pass would be constructed from the San Joaquin River at a point in Section 30, Township 13 South, Range 16 East, M.D.B. and M., to the mouth of the Merced River. This by-pass would be about 3000 feet wide and have sufficient capacity to carry all flood waters in excess of 7000 second-feet, which would pass down the river channel. East side tributaries would enter the by-pass through leveed channels extending to high ground. Backwater levees would be constructed along both banks of the river and Salt Slough for a sufficient distance upstream from the mouth of the Merced River to prevent overflow. A diversion weir would be constructed across the San Joaquin River just below the head of the by-pass to divert flows in excess of the capacity of the river channel. From the south end of the weir, a single levee would be constructed along the contour of the country to intercept the flow of Fresno Slough and divert it to the head of the by-pass. The by-pass would have capacities increasing from 46,000 second-feet at the inlet to 82,000 second-feet at the Merced River. It is estimated that the cost of these works, including the incidental reconstruction of irrigation canals and roads and the care of drainage, would be about $7,850,000. The area protected would be about 280,000 acres and the cost per acre about $28.

Under the other plan proposed, there would be no by-pass and the uncontrolled flood flows would be confined to a flood channel following the course of the San Joaquin River. The east levee of this channel would extend up the right bank of the river to high ground about eleven miles above Mendota Dam, and the west levee would extend up the left bank of Fresno Slough to high ground. East side tributaries would enter this channel through rectified leveed channels with the levees extended to high ground. A system of intercepting canals would conduct the run-off from the small creeks and drains into the heads of these inlet channels. Drainage from the west side would be collected and stored in the many large slough channels back of the levees and admitted to the main channel through culverts after the passage of the flood. The flood channel would vary from one-quarter to one-half mile in width, the average width being nearer the former figure. It would have capacities starting with 53,000 second-feet near the mouth of Fresno Slough and increasing as tributary streams enter through side channels to about 90,000 second-feet at the mouth of the Merced River. The cost of these works, including the incidental reconstruction of irrigation canals, roads and bridges, is estimated to be about $8,250,000. About 297,000 acres of land would be protected, however, and the cost would be a little less than $28 per acre, which is practically the same cost as under the other plan of protection.

Lower San Joaquin Valley—Mouth of Merced River to Paradise Dam—A flood control plan to protect lands along the San Joaquin River from the Merced River to Paradise Dam from maximum uncontrolled winter flood flows was formulated some years ago by the State Division of Engineering and Irrigation. Under this plan, levees would be constructed on each side of the river at a sufficient distance from its banks to provide a channel having the following capacities:

	Second-feet
Mouth of Merced River to mouth of Tuolumne River	105,000
Mouth of Tuolumne River to mouth of Stanislaus River	138,000
Mouth of Stanislaus River to Paradise Dam	160,000

All of these flows may be expected less than once in 250 years on the average.

The channel required for a flood of such magnitude would average 2400 to 3000 feet in width and about 15 per cent of the gross area subject to inundation would be required for levee right of ways and the flowage channel. The cost of such a project has been estimated during this investigation to be about $5,900,000, and as previously stated, the project is not considered economically feasible.

Flood damages in this section of the valley have been caused to a large extent by summer floods which have inundated the bottom lands during the early part of the growing season. Protection against such floods would also provide protection against the smaller winter floods. Therefore, a plan for protection against summer floods has been considered all that is required at the present time and, pending the adoption of a comprehensive plan for flood control for the entire valley, it has been the policy of the State Reclamation Board to grant permits for levee construction along this section of the river on the basis of protection against summer floods.

A flood control plan to provide for maximum uncontrolled summer flood flows was also formulated some years ago by the State Division of Engineering and Irrigation. Under this plan, levees would be constructed on each side of the river, but at a less distance apart than for protection against winter floods. The flood flows for which channel capacity would be provided are approximately those of the summer flood of 1906, and are as follows:

	Second-feet
Mouth of Merced River to mouth of Tuolumne River	56,000
Mouth of Tuolumne River to mouth of Stanislaus River	70,000
Mouth of Stanislaus River to Paradise Dam	79,000

These summer flood flows correspond to winter flood flows which may be exceeded once in 33 years, once in 14 years, and once in seven years, on the average, respectively. The degree of protection against uncontrolled winter floods, therefore, would not be the same along the different sections of the stream.

With this plan for flood protection, the levees would average 1500 to 1800 feet apart and about 4700 acres less land would be required for levee right of ways and the flowage channel than with adequate protection against maximum winter floods. The cost of the project from the mouth of the Merced River to Paradise Dam has been estimated during this investigation to be about $3,500,000 or $2,400,000 less than the cost of a project for the same area with protection against maximum uncontrolled winter floods.

San Joaquin Delta—It has been stated in a foregoing section of this chapter that although practically all of the San Joaquin Delta lands are now leveed, they are not protected against major floods. Analyses made by the State Division of Engineering and Irrigation and the United States Army Engineers of the carrying capacity of the existing channels in the delta under present conditions, shows that from Paradise Dam to the head of Middle River the channels have a capacity of 60,000 second-feet and from the head of Middle River to the Atchison, Topeka and Santa Fe Railroad, they have a capacity of about 100,000 second-feet. Below the Santa Fe railroad more channel capacity exists, especially since the dredging of the Stockton Ship Canal. However, owing to the small capacity of the San Joaquin River main channel from the head of Middle River to its junction with the Ship Canal, the total flood carrying capacity of the lower channels does not become available to floods of the San Joaquin Valley until the vicinity of Venice Island is reached. It may be said, therefore, that the lands lying between Paradise Cut and Tom Paine Slough and between Paradise Cut and the San Joaquin and Middle rivers, and those lands east of the main San Joaquin River from Paradise Dam to and including the city of Stockton, comprising about 50,000 acres of reclaimed lands, have protection against a flood of only 60,000 second-feet discharge. Allowing for encroachment on the levee freeboard, it is possible that 70,000 second-feet might pass without breaking the levees and inundating the lands. The frequency curves for the San Joaquin River below its confluence with the Stanislaus River on Plate LXXV, show that a flow of 70,000 second-feet may occur, under conditions without reservoir control, on an average of 21 times in 100 years. For that portion of the delta lying west of the San Joaquin River and between the head of Middle River and Venice Island, it is estimated that reasonable protection is afforded by existing works against a flood of 100,000 second-feet. Reference to the frequency curves on Plate LXXV shows that a flow of this size may be exceeded on an average of about five times in 100 years.

Several plans for protecting the delta lands against winter floods uncontrolled by reservoirs were formulated several years ago by the United States Army Engineers, the State Reclamation Board, and the State Division of Engineering and Irrigation, cooperating. One of these plans appears to be as effective as any of the others and considerably less expensive. In general, this plan calls for a by-pass and the enlargement of existing channels from Paradise Dam to the vicinity of the Atchison, Topeka and Santa Fe Railroad. North of the railroad, the overflow channels of Middle and Old River would be kept clear of trees and brush and the existing channels, including the Stockton Ship Canal, would carry the flood waters to the lower San Joaquin River through which they would pass to Suisun Bay. Some channel improvement and raising of levees along several of the existing channels would be necessary. The by-pass would follow Paradise Cut with a width of about 2500 feet. It would then cross Union Island, where its width would be 1050 feet, and follow Middle River, with a width of about 1800 feet, to the Santa Fe railroad. The system was designed for a flood carrying capacity of 175,000 second-feet at Paradise Dam with increased quantities below the mouths of the Calaveras and Mokelumne rivers. With such a plan, however, flood plane elevations in the channels north of the Santa Fe railroad would range from about twelve feet,

U. S. Army Engineer datum, near the mouth of Dutch Slough, to fifteen to seventeen feet near the Santa Fe railroad. It has been stated* by G. A. Atherton, general manager of the California Delta Farms, Inc., that in his opinion elevation 13.3 feet, United States Engineer datum, would be a reasonable elevation at which the levees in the lower delta could be maintained permanently. It would appear, therefore, that the flood plane elevations of the proposed flood control plan for the delta would cause the overtopping or breaking of levees in the lower delta. It was roughly estimated by the Army Engineers at the time this plan was formulated that the necessary works, including the lengthening of Paradise Dam, would cost about $10,000,000.

Since the estimated flood flow at Paradise Dam during a summer flood similar to that of 1906 is 79,000 second-feet and the capacity of the San Joaquin River and Paradise Cut below that point is only 60,000 to 70,000 second-feet, some flooding by levee breaks between Paradise Dam and the head of Middle River would probably occur. Protection from such breaks could be provided by improving the channel of Paradise Cut, or that of the San Joaquin River above Middle River, to give greater capacity. Below the head of Middle River the present capacity of 100,000 second-feet would be sufficient. No cost for such improvement has been estimated, but it would not be a large amount.

Control of Floods by Reservoirs.

The control of floods by reservoirs has been a subject of intensive study. It has been believed by some persons that any reservoir constructed for power or irrigation purposes will diminish flood flows. Reservoirs utilized for these purposes alone, however, may be allowed to fill as rapidly as water is available and remain full until after the flood season has passed. They, therefore, are apt to have no reserve space, or only a small amount of space, available for controlling floods when they occur, and dependence can not be placed upon them for this purpose. On the other hand, reservoirs constructed and operated for flood control purposes alone will usually make the cost of protection by this means greater than if it were obtained by leveed channels and by-passes. In such reservoirs, the entire space is dedicated to flood control and after the passage of a flood the reservoir is emptied and held empty in anticipation of a succeeding flood.

The control of floods by reservoirs was considered in 1910 by the California Debris Commission at the time it was formulating its plan for flood control in the Sacramento Valley. It, however, investigated the effect of reservoirs which were relatively small compared with the major reservoir units of the State Water Plan. The sites also were located at points well above the valley floor and controlled only a small portion of the drainage area. Since the reservoir capacity was small, the flood controlled was only a small portion of that at the valley floor line, and the reservoirs were to be utilized only for flood control purposes, it was the conclusion of the Debris Commission that partial control by reservoirs was not economical and this feature was not

* Bulletin No. 22, "Report on Salt Water Barrier," Division of Water Resources, 1929, page 46.

included in the plan. It did include in its report,* the following statement:

> "While favoring the use of reservoirs as far as possible, and considering that one of the advantages of the project herein proposed is that it lends itself to future storage possibilities, the Commission believes that it is not economical to construct reservoirs for flood control, but that such construction should be deferred until these reservoirs prove desirable for power and irrigation purposes."

In the studies of the control of floods by reservoirs by this office, particular attention has been given to the coordination of flood control with conservation in the utilization of reservoirs and a report** was rendered on this subject. It is demonstrated in that report that by utilizing varying amounts of space in a reservoir, guided by the times of occurrence of floods and the preceding climatological conditions, a substantial degree of flood control can be obtained on the larger streams of California without impairment of the conservation value of major reservoirs on those streams.

Utilization of Reservoirs of State Water Plan for Flood Control.

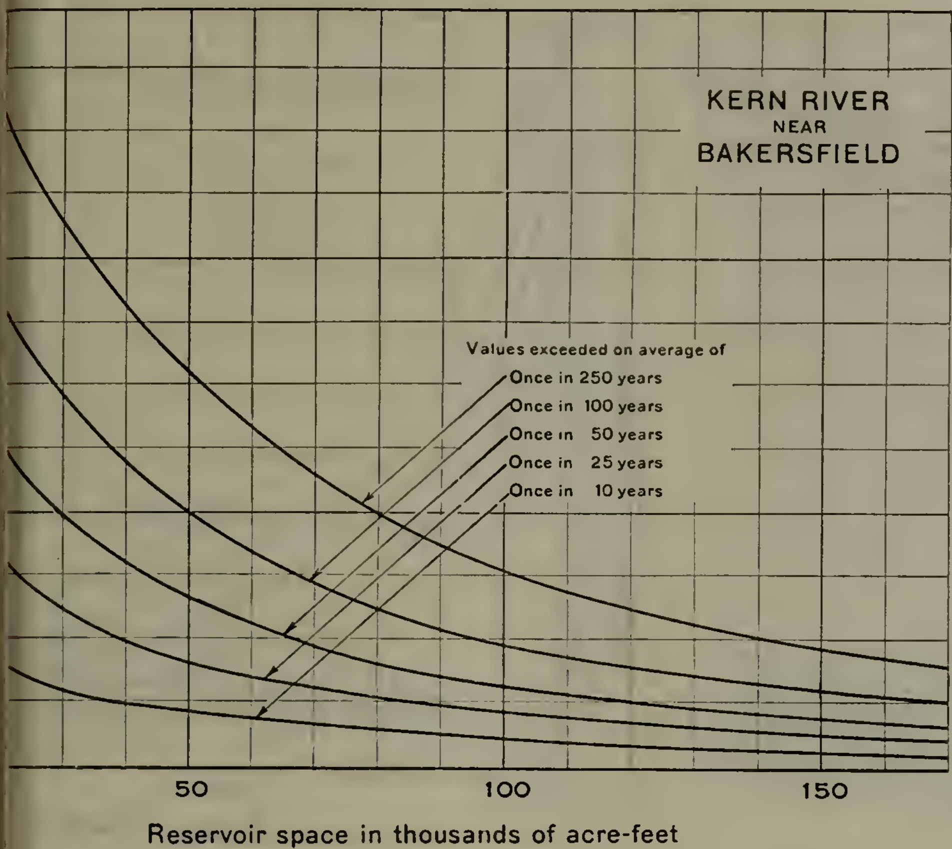
The major reservoir units of the State Water Plan in the San Joaquin River Basin would be located near the line of the valley floor, and therefore offer favorable opportunities for the reduction of flood flows on the major streams of the basin at the points where they would discharge onto the valley floor. This reduction would increase the degree of protection afforded by the works already constructed or permit lower levees and smaller channels in the portions of the valley not yet protected. To obtain the greatest flood control value, the reservoirs would be operated for this purpose as one of their primary functions. If not operated specifically for flood control, they might absorb many of the medium and small floods but would fail to control floods in years of large run-off since the reservoir would probably be filled or have insufficient reserve space in such years.

The volumes of flood discharge during winter floods at the foothill gaging stations, as indicated by the frequency curves shown on Plate LXXIV, and at points of concentration below stream confluences on the valley floor, as indicated by the right-hand curves on Plate LXXV, are those that may be expected to occur under natural conditions with no artificial interference other than the confinement of flood flows to leveed channels across the valley floor areas. To control these flows to smaller amounts, the flood waters could be stored in major reservoir units of the State Water Plan and released at a predetermined rate. The amounts of reservoir space required in the vicinity of each foothill gaging station to reduce floods at that point to certain controlled flows, and also the frequency with which these controlled flows may be exceeded with the space reserved for this control, were estimated from studies made for that purpose.

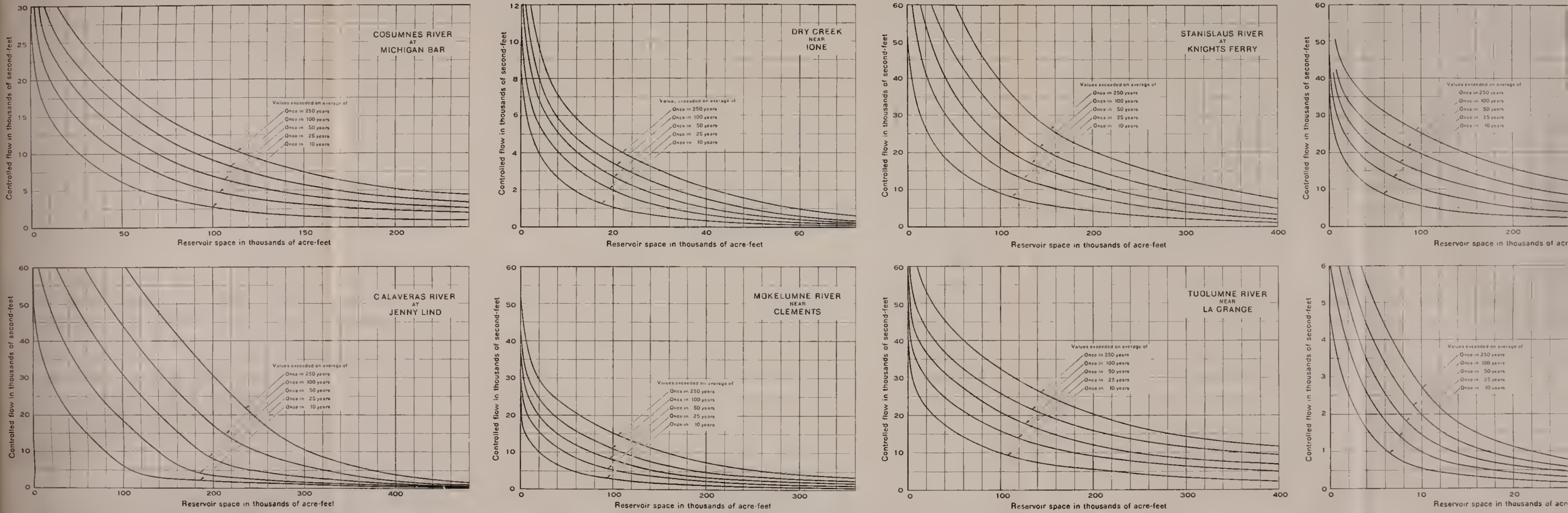
The amounts of reservoir space which would be exceeded at certain frequencies in controlling the winter floods at each of the gaging stations to various controlled flows are shown by the curves on Plate LXXVI, "Reservoir Space Required to Control Floods on Major Streams of San

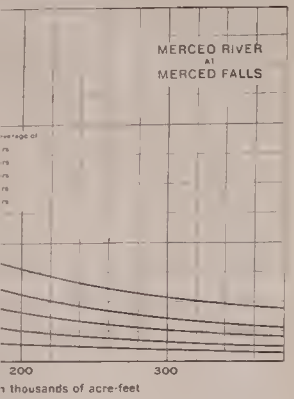
* House Document No. 81, 62d Congress, First Session.

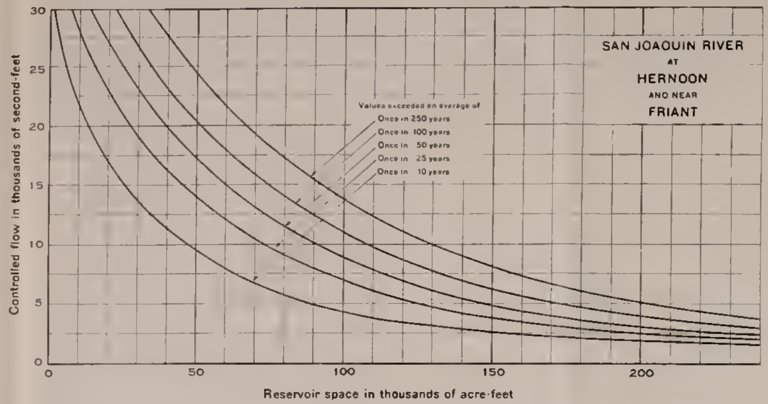
** Bulletin No. 14, "The Control of Floods by Reservoirs," Division of Engineering and Irrigation, 1928.

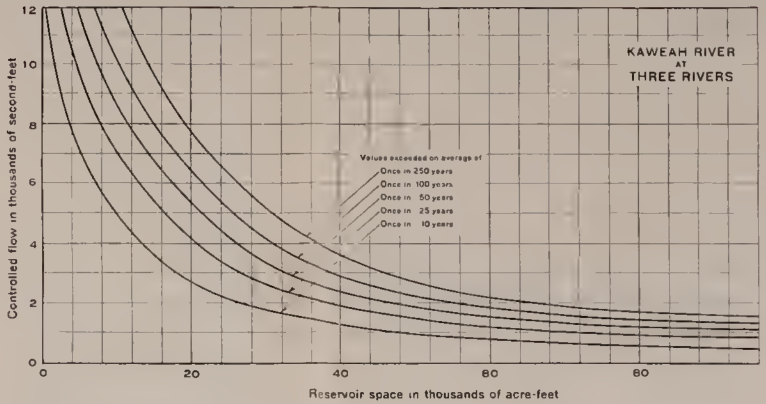


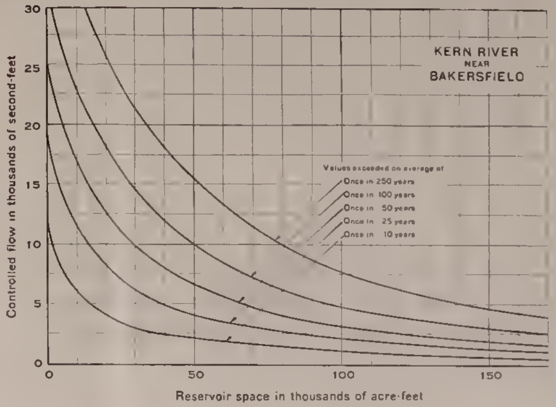
ESERVOIR SPACE REQUIRED
TO CONTROL FLOODS
ON
MAJOR STREAMS
OF
SAN JOAQUIN RIVER BASIN

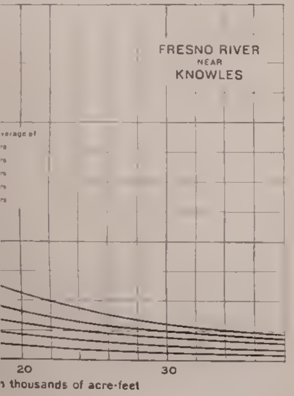

COSUMNES RIVER AT MICHIGAN BAR
DRY CREEK NEAR IONE
STANISLAUS RIVER AT KNIGHTS FERRY
CALAVERAS RIVER AT JENNY LIND
MOKELUMNE RIVER NEAR CLEMENTS
TUOLUMNE RIVER NEAR LA GRANGE
Values exceeded on average of
Once in 250 years
Once in 100 years
Once in 50 years
Once in 25 years
Once in 10 years
Controlled flow in thousands of second-feet
Reservoir space in thousands of acre-feet

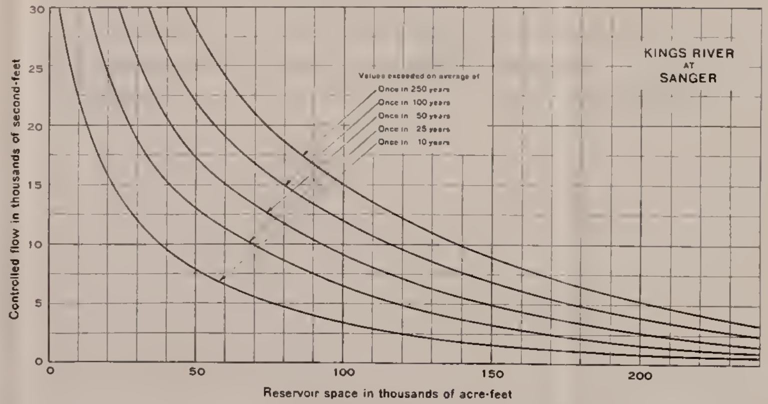


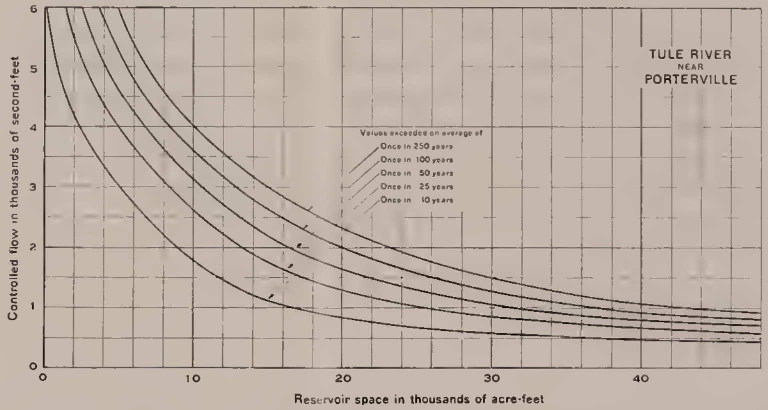












RESERVOIR SPACE REQUIRED
TO CONTROL FLOODS
ON
MAJOR STREAMS
OF
SAN JOAQUIN RIVER BASIN

Joaquin River Basin." The data from which these curves were developed were taken from Tables 187 to 199, inclusive. These tables show the probable winter or rain water flood flows and run-offs, which would be exceeded at selected intervals of time, on the average, in the major streams of the San Joaquin River basin, as indicated by the frequency curves on Plate LXXIV. The method by which the reservoir space curves were developed was the same for each stream and for each selected frequency. It is given in the following description of the development of the curve of reservoir space which would be exceeded once in 100 years on the average in controlling the Tuolumne River. This analysis has been based on the data presented in Table 194, columns 8 and 9, in which are listed the total run-offs in acre-feet and the mean flows in second-feet for periods one to ten days in length. In this table the probable volume of flow for a one-day period is 106,100 acre-feet and the mean flow for that period is 53,500 second-feet. If the flow were all stored so that there would be none below the dam, the amount of reservoir space in use at the end of the day would be 106,100 acre-feet. If a flow of 53,500 second-feet below the dam were permissible, no reservoir space would be in use at the end of the day.

Points representing these two pairs of flow and reservoir space values were plotted on a graph on which the horizontal scale represented reservoir space in acre-feet and the vertical scale controlled flow in second-feet, and a straight line connecting the two points was drawn. This line was the locus of all points representing the reservoir space in use at the end of the one-day period for any selected controlled flow. Similar lines were developed for the 2, 3, 4, 6, 8 and 10-day periods for which data were available. An inspection of Table 194, columns 8 and 9, shows that the one-day period has the largest mean flow in second-feet of any period studied, and the smallest total run-off in acre-feet, while the ten-day period has the smallest mean flow in second-feet and the largest total run-off in acre-feet. When drawn on the graph, therefore, the lines representing the relation between controlled flow and reservoir space for each time period formed a grid of intersecting lines bounded on the right by a broken line extending from the point representing a controlled flow of 53,500 second-feet and zero reservoir space along the line for a one-day period to its intersection with the two-day period line, along that line to its intersection with the three-day period line, and so on along each period line in turn to the intersection of the ten-day period line with the line of zero controlled flow at a reservoir space of 509,800 acre-feet. Had the increment of time of each period been infinitely small, each segment of this broken line would have been infinitely short and the line would have been a curve. This curve, however, would intersect the line of zero storage at a controlled flow value equal to the crestflow of the flood and would approach a controlled flow value equal to the mean daily flow of the river at infinity. Since the accuracy of the stream flow data available does not justify further refinement, the curve shown on Plate LXXVI for the once in 100 year frequency was drawn tangent to each segment of the broken line and the two ends were located as described in the last preceding sentence.

The amounts of reservoir space required to control floods to certain flows exceeded with various frequencies, as obtained from the curves on Plate LXXVI, are given in Table 203.

TABLE 203

RESERVOIR SPACE REQUIRED TO CONTROL WINTER FLOODS ON MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

Stream and location of point of control	Controlled flow, in second-feet	Reservoir space, in acre-feet, required to prevent controlled flow being exceeded on average of more than once in:				
		10 years	25 years	50 years	100 years	250 years
Kern River near Bakersfield	7,500	5,900	23,000	43,200	67,000	101,500
	10,000	1,700	14,000	29,100	49,500	79,100
	15,000	0	4,000	13,800	28,900	51,800
	20,000	0	0	5,300	15,500	31,000
Tule River near Porterville*	2,000	8,900	13,300	16,400	19,800	23,000
	4,000	2,400	4,900	6,700	8,500	10,100
	6,000	200	1,400	2,500	3,700	4,900
Kaweah River at Three Rivers	2,000	26,200	37,100	46,600	55,000	65,700
	6,000	7,300	13,000	17,400	21,500	26,200
	12,000	400	2,400	4,600	6,900	10,500
Kings River at Piedra	5,000	76,500	118,500	148,500	178,000	204,500
	15,000	21,500	41,500	60,000	80,000	100,000
	25,000	7,500	19,500	31,500	42,500	57,500
San Joaquin River near Friant	5,000	89,000	125,000	117,000	172,500	203,000
	15,000	26,000	45,000	60,000	75,000	92,000
	25,000	5,500	15,500	25,000	34,500	48,000
Fresno River near Knowles	750	7,800	12,400	16,700	21,400	26,700
	3,000	1,400	3,200	5,000	6,900	9,200
	4,500	100	1,300	2,600	4,000	5,800
Merced River at Merced Falls	10,000	50,000	101,000	162,000	223,000	327,000
	20,000	12,500	32,000	57,000	95,000	146,000
	25,000	6,000	16,500	33,000	59,000	100,000
	30,000	2,500	8,500	18,000	34,000	66,500
Tuolumne River near La Grange	15,000	56,000	108,500	156,000	214,000	284,000
	20,000	29,000	68,000	107,000	149,500	204,000
	30,000	5,000	21,000	46,500	73,500	116,000
	40,000	500	3,500	12,500	30,000	61,500
Stanislaus River at Knights Ferry	10,000	90,000	162,000	221,000	279,000	315,000
	15,000	56,000	106,000	153,000	204,000	262,000
	30,000	14,000	41,500	68,000	101,000	136,000
	40,000	5,500	22,000	41,500	68,000	98,000
Calaveras River at Jenny Lind	7,500	91,500	153,000	205,000	280,000	335,000
	15,000	59,000	115,000	162,000	211,000	269,000
	25,000	29,000	75,000	122,000	165,000	223,000
	45,000	3,000	25,500	59,500	97,500	150,000
Mokelumne River near Clements	5,000	56,000	104,000	147,000	192,000	264,000
	10,000	21,000	48,500	78,000	110,000	157,000
	20,000	1,500	8,000	20,000	36,000	61,000
	30,000	0	500	3,500	8,000	19,500
Dry Creek near Ione	2,000	11,500	19,800	26,300	33,200	41,500
	4,000	4,100	8,300	12,400	16,300	22,000
	5,000	2,500	5,200	8,400	11,300	15,900
	6,000	1,500	3,200	5,600	7,800	11,400
Cosumnes River at Michigan Bar	5,000	61,200	98,000	133,000	166,000	209,000
	15,000	10,500	25,100	39,800	56,300	73,300
	25,000	1,000	4,600	9,400	17,200	28,800

*Figures apply to main fork of Tule River only. For the combined flows of the main river and the South Fork (as measured at Success), the reservoir space required to obtain controlled flows, exceeded not more than once on the average in 100 years, of 2,000, 4,000, and 6,000 second-feet would be 33,800, 17,200 and 8,600 acre-feet respectively.

In the San Joaquin River Basin, it will be necessary to control summer floods as well as winter floods if the desired controlled flow is less than the maximum flow during a summer flood less diversions for irrigation and absorption into the underground basins. Records are now being obtained each year of the water content of snow packs in the Sierra Nevada on various dates and of stream flows throughout the year. It should be possible, therefore, to establish a fairly definite relation between snow pack and stream flow and from this to predict summer flows. With such predicted flows on any stream, the amount of reservoir space required to control these flows to a fixed amount can be determined and reserved as long as it may be required. After giving due consideration to the type, size and character of floods in the San Joaquin River Basin, the following general rule has been formulated for use in operating the reservoirs of the State Water Plan in that basin for flood control:

> Some space shall be held in reserve for flood control from November 1st to May 1st whenever the total precipitation up to any date in that period is more than 50 per cent of the normal precipitation to the same date. The flood control reserve shall be increased at a uniform rate from zero on November 1st to the maximum amount on December 1st. The maximum space shall be held in reserve from December 1st to April 1st, except for the decrease during the control of flood flows, and then decreased at a uniform rate to zero on May 1st, except as follows: When snow surveys indicate that flows after April 1st will exceed the sum of the controlled flow and releases from the reservoir for irrigation and underground storage, space for flood control shall be reserved during such periods and in such amounts as to obtain the desired controlled flow.

This rule would give satisfactory operation of reservoirs on streams rising at high elevations since these reservoirs would have snow water run-off after April 1st to fill the space reserved for flood control. However, to obtain satisfactory water supplies for irrigation from reservoirs dependent entirely or largely upon rain water run-off for a water supply. it is probable that the amount of reserve space should and would be varied with climatological conditions affecting run-off throughout the year.

There are given in Table 204 for each reservoir in the San Joaquin River Basin in which it is proposed to reserve space for flood control, the maximum amount of space to be reserved, the controlled flow just below the reservoir, and the frequency with which the controlled flow would be exceeded with the space reserved. These data are based on studies of winter floods. Other studies, however, show that with the same or a smaller amount of space reserved in each reservoir for controlling summer floods, the controlled flow during such floods would not exceed the controlled flow shown in the table plus diversions near

TABLE 204

SPACE TO BE RESERVED IN RESERVOIRS OF STATE WATER PLAN FOR CONTROLLING FLOODS TO CERTAIN SPECIFIED AMOUNTS

Reservoir	Stream	Point of control	Controlled flow, in second-feet	Maximum space reserved, in acre-feet	Number of times controlled flow will be exceeded, on the average
Isabella	Kern River	Near Bakersfield	7,500	67,000	Once in 100 years
Pine Flat	Kings River	Piedra	15,000	80,000	Once in 100 years
Friant	San Joaquin River	Near Friant	15,000	75,000	Once in 100 years
Exchequer	Merced River	Merced Falls	25,000	59,000	Once in 100 years
Don Pedro	Tuolumne River	Near La Grange	15,000	214,000	Once in 100 years
Melones	Stanislaus River	Knights Ferry	15,000	204,000	Once in 100 years
Valley Springs	Calaveras River	Jenny Lind	25,000	165,000	Once in 100 years
Pardee	Mokelumne River	Near Clements	10,000	[1]0	Once in 100 years
Ione	Dry Creek	Near Ione	5,000	[1]121,000	Once in 100 years
Nashville	Cosumnes River	Michigan Bar	15,000	56,000	Once in 100 years

[1] Floods which would cause flows in excess of the controlled flow of 10,000 second-feet in the Mokelumne River at Clements would be diverted from the Pardee Reresvoir to Dry Creek by the Jackson Creek spillway and the water stored in Ione reservoir.

the reservoir for irrigation and underground storage. A channel having sufficient capacity to carry controlled winter flows below these points of diversion, therefore, would also have sufficient capacity to carry controlled summer floods.

Assuming that the reservoirs listed in Table 204 had been constructed and operated for flood control during the period of stream flow record in the San Joaquin River Basin and that winter floods had been controlled to the amounts shown in the table, estimates were made of the winter flood flows at the points of concentration just below the confluences of the San Joaquin River with the Merced, Tuolumne, Stanislaus and Sacramento rivers. These estimates were made in the same manner as in the previous studies of concentrated flows except that controlled flows were used instead of the uncontrolled ones. For the station at the confluence of the San Joaquin and Sacramento rivers, the concentration values are affected by the contributions from the Sacramento River and were computed by adding to the estimated concentrations of the Sacramento River at Sacramento and the Yolo By-pass at Lisbon, with reservoir control,* the estimated controlled flows in the San Joaquin River below its confluence with the Stanislaus River and the controlled flows from the Calaveras River at Jenny Lind, Mokelumne River near Clements, and Cosumnes River at Michigan Bar.

With the values of concentrated flows thus obtained, frequency curves were drawn in the same manner as previously described for the foothill gaging stations. These curves are shown on Plate LXXV and are in each case the left-hand curve for the station, designated "with reservoir control." The amounts of flow at the four points of concentration that would be exceeded with certain frequencies are shown in Table 205.

TABLE 205

PROBABLE FREQUENCIES OF WINTER FLOOD FLOWS AT SELECTED POINTS OF CONCENTRATION ON LOWER SAN JOAQUIN VALLEY FLOOR

With Reservoir Control

Stream and point of concentration	Probable maximum mean daily flow, in second-feet, exceeded on average of once in:			
	10 years	25 years	50 years	100 years
San Joaquin River below confluence of San Joaquin and Merced rivers	37,500	44,000	48,000	51,000
San Joaquin River below confluence of San Joaquin and Tuolumne rivers	52,500	58,500	62,000	64,000
San Joaquin River below confluence of San Joaquin and Stanislaus rivers	67,000	74,500	78,000	82,000
San Joaquin and Sacramento rivers at confluence	435,000	505,000	550,000	595,000

In Table 206, comparisons are made for four frequencies of occurrence, of the sizes of floods which would concentrate at the four valley floor points without and with reservoir control.

Flood Control Benefits from Reservoirs of State Water Plan.

Since the degree of protection afforded by levees in some parts of the San Joaquin Valley is difficult to determine, comparison of degrees of protection without and with flood control by reservoirs in all parts

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931, page 129.

TABLE 206

COMPARISON OF WINTER FLOOD FLOWS AT SELECTED POINTS OF CONCENTRATION ON LOWER SAN JOAQUIN VALLEY FLOOR

Without and With Reservoir Control

Frequency with which floods may be exceeded—times in 100 years on the average	Probable maximum mean daily flow, in second-feet, in San Joaquin River below confluence of San Joaquin River and:							
	Merced River		Tuolumne River		Stanislaus River		Sacramento River	
	Without reservoir control	With reservoir control[1]	Without reservoir control	With reservoir control[1]	Without reservoir control	With reservoir control[1]	Without reservoir control	With reservoir control[2]
1	69,500	51,000	103,000	64,000	133,000	82,000	780,000	595,000
2	62,000	48,000	92,000	62,000	118,000	78,000	680,000	550,000
4	53,000	44,000	80,000	58,500	104,000	74,500	592,000	505,000
10	42,000	37,500	64.000	52,500	86,000	67,000	490,000	435.000

[1] With flows controlled to amounts shown in Table 204.
[2] With flows in San Joaquin Valley controlled to amounts shown in Table 204 and the following controlled flows in the Sacramento Valley: Sacramento River at Red Bluff, 125,000 second-feet; Feather River at Oroville, 100,000 second-feet; Yuba River at Smartsville, 70,000 second-feet; Bear River at Van Trent, 20,000 second-feet, and American River at Fair Oaks, 100,000 second-feet.

has not been attempted. It is possible, however, to estimate some of the savings which may be effected in protecting the land in some parts of the valley if flood control by reservoirs is provided, and the increased degree of protection afforded by present works in other parts.

Upper San Joaquin Valley South of San Joaquin River—Present conditions in the San Joaquin Valley south of the San Joaquin River and plans for protecting the lands from floods uncontrolled by reservoirs have been described in earlier parts of this chapter. It was shown that the waters of the Kern, Tule and Kaweah rivers which are not used for irrigation or underground storage, and those of the Kings River which are not used for the same purpose or do not flow northward to Fresno Slough, reach the bed of Tulare Lake. It was also shown that if these waters reach the lake in sufficient quantities, some lands in the lake bed will be inundated, although they now have levee protection.

The construction of the reservoirs of the State Water Plan and their utilization for conservation purposes under a condition of ultimate development would materially benefit the lands in Tulare Lake by reducing the amounts of water reaching the lake. With the reservoirs operated for conservation purposes alone, however, more water would reach the lake in a wet year than could be cared for by the reservoir in the bed of the lake and flooding of other lands adjacent to the reservoir would occur. To prevent this, the by-pass canal around the west side of the lake or the cut from Tulare Lake reservoir to Fresno Slough, previously described, would probably be required although the capacity of either channel would probably be less than under present conditions without any storage reservoirs.

It is proposed in the operation of the State Water Plan, however, to use the Isabella and Pine Flat reservoirs for conservation and flood control and the Pleasant Valley reservoir for conservation only. The utilization of 67,000 acre-feet of storage space in the Isabella Reservoir for flood control would reduce winter floods in the Kern River near Bakersfield to 7500 second-feet exceeded once in 100 years on the average. This flow could be confined to the present natural and leveed channels, and canals below Bakersfield, without damage to adjacent lands. During summer floods it is proposed to control the flows to 9000 second-feet at the reservoir since 1500 second-feet would be diverted into the Kern River canal of the State Water Plan at a point near the mouth of Kern River Canyon. Since summer flows of record have exceeded 9000 second-feet by only small amounts and for relatively short periods, it is probable that only a small portion of the 67,000 acre-feet of reservoir space will ever be required for the control of summer floods.

For the control of floods on the Kings River, it is proposed to utilize 80,000 acre-feet of space in the Pine Flat reservoir. With this reserve space, winter floods could be controlled to 15,000 second-feet exceeded once in 100 years on the average, through the Kings River Delta. This flow would be carried through existing channels and, if desired, could be diverted northward into the San Joaquin River through Fresno Slough. In any case, 10,000 second-feet of this flow would have to be diverted to Fresno Slough, unless some water is diverted for irrigation or underground storage uses, because the channel leading to Tulare Lake has a capacity of only 5000 second-feet. During summer floods, the flow from the reservoir would be controlled to 15,000 second-feet plus the amounts of water which could be diverted through canals taking water out of Kings River. The maximum capacity of these canals is about 10,000 second-feet and all or nearly all of this capacity could be used during the passage of the peak flow of a summer flood. The controlled flow below all diversions would not exceed 15,000 second-feet. Since records of summer floods indicate that flows in excess of 25,000 second-feet will occur infrequently and for only a short time, it is probable that the reserve storage space required to control such floods will be only a small portion of that required for winter floods.

In order to determine the effect of the operation of the State Water Plan on flood conditions in the upper San Joaquin Valley, and especially in Tulare Lake, a study was made carrying the operation through several years. In this study, it was assumed that all works of the plan were constructed and in full operation to supply water for irrigation and absorption into the underground basins as described in Chapter VII, and that the Isabella and Pine Flat reservoirs were operated to control winter and summer floods as described in the foregoing paragraphs. It was further assumed that surplus Kern River water would have been stored in Buena Vista Lake until both the irrigation reservoir and the reserve space were filled and that water spilled from the lake would have flowed northward to Tulare Lake, which it would have reached undiminished in quantity. It is likely, however, that a considerable portion of this water would be used before reaching Tulare Lake and the amount of filling of the lake would not be as great as estimated.

Tulare Lake was practically empty in 1905 and would undoubtedly have been dry under conditions of ultimate development in the upper San Joaquin Valley. The study was therefore started with this year, and was carried through 1929. This period includes several winter floods of major importance and the summer flood of 1906 which was the largest summer flood of record. In the study, 5000 second-feet of the controlled flow of the Kings River was diverted to Tulare Lake during winter floods but all of the residual 15,000 second-feet of controlled flow was diverted to Fresno Slough and the San Joaquin River during summer floods.

Under these conditions, the 209,000 acre-feet of capacity in Buena Vista Lake would have been fully utilized in 1906 and 1916 only. In 1906, 8700 acre-feet of water would have been spilled from the lake and 484,000 acre-feet would have spilled in 1916. This spill water was assumed to have reached Tulare Lake undiminished in quantity. After receiving this spill water from Buena Vista Lake, Tulare Lake would have filled to a maximum stage of 175,000 acre-feet in 1906 and to a stage of 532,000 acre-feet in 1916. These are the only two years in which the capacity of 140,000 acre-feet below elevation 192, or a level three feet below the tops of the surrounding levees, in the reservoir in the north half of Township 22 South, Range 20 East, M.D.B. and M., would have been exceeded. The surplus water in 1906 would not have exceeded the capacity of the auxiliary reservoir in the south half of the same township. The large amount of water reaching the lake in

1916, however, would have exceeded the 350,000 acre-foot capacity of the main and auxiliary reservoirs below elevation 195, the level of the tops of the surrounding levees, and at least two adjacent reclaimed areas, with an area of 13,700 acres, would have been required. Even with these areas flooded, the water would have stood at elevation 194.5 or almost to the tops of most of the levees in the vicinity. However, since this critical condition in Tulare Lake was caused mainly by Kern River water, considerable improvement would have resulted from spreading part of this water on the area between Buena Vista and Tulare lakes.

In controlling the summer floods which occurred during the period studied, the maximum reserve space required in the Isabella reservoir would have been 4500 acre-feet and the maximum space required in the Pine Flat reservoir would have been 5000 acre-feet. During most of the winter floods, the reservoirs would not have filled to flood control stage until well after the peak flows had passed and it would never have been necessary to release the full controlled flow during such floods. During some of the larger summer floods, however, the full controlled flow on the Kern River would have reached Buena Vista Lake for a considerable period and the 15,000 second-foot flow from Kings River would have flowed down Fresno Slough to join the San Joaquin River flows for three days in June, 1906, and a maximum of about 10,000 second-feet from Kings River would have reached the San Joaquin River in June, 1909.

The foregoing study shows that with the exception that the crops on 13,700 acres of land in the bed of Tulare Lake outside of the area reserved for storage would probably have been flooded and lost in one year, the same protection from floods would have been provided to lands in the bed of Tulare Lake by the operation of the units of the State Water Plan for conservation and flood control as would have been provided by the cut through Summit Lake Ridge proposed by A. D. Schindler and hereinbefore described. The operation of the units of the State Water Plan would therefore result in a saving of at least \$1,200,000 in the cost of flood protection works. If the comparison is made using the by-pass canal around the lake instead of the Summit Lake Ridge cut, the saving in cost is about \$2,200,000. With the by-pass canal, however, the auxiliary lake bed reservoir would probably not be required.

Under the initial development of the State Water Plan, no reservoir units are proposed in the San Joaquin Valley south of the San Joaquin River. While there would be some benefit from the spreading of water and its absorption into the underground basin under this development, the benefit from the storage of flood flows would be lacking and both rates and volumes of flow during some floods would be such as to cause considerable damage.

Upper and Lower San Joaquin Valleys—Herndon to Mouth of Merced River—In estimating flood flows in the San Joaquin River above the mouth of the Merced River with floods controlled by the reservoirs of the State Water Plan, flows from the upper San Joaquin Valley south of the San Joaquin River, as estimated in the study just described, were combined with controlled flows from the Friant reservoir and inflows from tributary streams between the reservoir and the Merced River.

The controlled flow from the Friant Reservoir during winter floods was limited to 15,000 second-feet but it was found that the flow below the dam would never have reached this amount, because the reservoir was always below flood control stage during the passage of flows in excess of 15,000 second-feet. Summer flows were controlled by the reservoir to 15,000 second-feet downstream from the diversions of the Madera and San Joaquin River-Kern County canals. The Madera Canal was assumed to divert 1500 second-feet throughout all summer floods and the San Joaquin River-Kern County Canal was assumed to divert 3000 second-feet at all times throughout the summer when local supplies from the Kern, Tule and Kaweah rivers were not so great that this amount could not be used for consumptive use and absorption in the area served by the canal. Drafts from the reservoir during summer floods, therefore, were 19,500 second-feet except during parts of May and June, 1906.

With the foregoing conditions, the maximum combined flow from the upper San Joaquin Valley at Mendota Dam, would have been 30,000 second-feet during the summer flood of 1906. From this amount about 5000 second-feet would have been diverted into canals in the vicinity of Mendota Dam, leaving 25,000 second-feet to be cared for by the San Joaquin River flood channel. Studies of summer flood frequencies indicate that the maximum mean daily flow in the San Joaquin River at Friant during the 1906 flood was of a magnitude which may be expected to be exceeded about twice in 100 years on the average and that the maximum total 36-day run-off during the same flood may be expected to be exceeded only about once in 100 years on the average.

For the reach of the San Joaquin River from Mendota Dam to the mouth of the Merced River, the estimated flood concentrations resulting from a winter flood similar to that of 1911, with the releases from the Pine Flat and Friant reservoirs controlled as stated in the foregoing paragraphs, are as follows:

Mendota Dam to Fresno River	16,000 second-feet
Fresno River to Chowchilla River	26,000 second-feet
Chowchilla River to Mariposa Creek	33,000 second-feet
Mariposa Creek to Bear Creek	36,000 second-feet
Bear Creek to Salt Slough	42,000 second-feet
Salt Slough to Merced River	50,000 second-feet

It is estimated that the 1911 winter flood in this section of the valley was one which would be exceeded about once in 100 years on the average and the foregoing flows, therefore, may be expected to be exceeded with the same frequency.

To care for the flows given in the foregoing table in the San Joaquin River channel, only 16,000 second-feet capacity would be required between Mendota Dam and the mouth of Fresno River. However, since the minor tributaries contribute very little or no flow to the summer floods, the flood channel from Mendota Dam to the mouth of the Merced River would safely carry summer floods similar to that of 1906 if it were designed to have a capacity of 25,000 second-feet, instead of 16,000 second-feet, from Mendota Dam to the mouth of Fresno River. This has been done in the following estimate of cost.

To provide protection against flows of the foregoing amounts, a flood channel following the course of the San Joaquin River would be adequate. The cost of such a channel, together with all incidental works such as drainage culverts, the construction of levees to high ground along the streams entering the San Joaquin River from the east side, and the extension of existing bridges, is estimated to be about $4,000,000. With such works there would be about 297,000 acres of land protected and the cost would be about $13.50 per acre. Reference to the foregoing estimate of cost for the protection of the same lands against uncontrolled flows with a similar plan for a flood channel shows that the operation of the State Water Plan as hereinbefore described would reduce the cost of protection along the San Joaquin River from Herndon to the Merced River about $4,250,000 and the cost per acre about $14.50. The degree of protection in both cases would be the same.

The foregoing benefits are those which would accrue from the operation of the State Water Plan under conditions of ultimate development. Under the initial development of the plan, the Friant Reservoir would be the only reservoir unit constructed in the valley above the Merced River. This reservoir while being operated for conservation purposes would have a material effect in reducing flood flows in the San Joaquin River, and its operation for flood control would increase this effect. A study of the reservoir under conditions of initial development shows that during the floods of 1911, the maximum mean daily flow in January of about 36,000 second-feet which would have occurred under present conditions of storage in the mountain watershed above Friant would have been reduced by the operation of the Friant Reservoir to about 3500 second-feet. Another maximum mean daily flow in March, 1911, of about 19,000 second-feet would have been reduced to about 10,500 second-feet. The controlled flows during summer floods would be the same as with the operation of the reservoir under conditions of ultimate development.

Lower San Joaquin Valley—Mouth of Merced River to Paradise Dam—As previously stated, it is judged uneconomical to provide protection against uncontrolled winter floods in the San Joaquin River from the mouth of the Merced River to Paradise Dam, and protection has been and probably will be provided only against uncontrolled summer floods similar to that of 1906, the flows during which are estimated to be:

Merced River to Tuolumne River	56,000 second-feet
Tuolumne River to Stanislaus River	70,000 second-feet
Stanislaus River to Paradise Dam	79,000 second-feet

When protection has been provided against such floods, the degree of protection in each division against uncontrolled and controlled winter floods, as shown by the curves on Plate LXXV, will be:

Division—	Number of times in 100 years flows would be exceeded — Without reservoir control	With reservoir control
Merced River to Tuolumne River	3	Less than 1
Tuolumne River to Stanislaus River	7	Less than 1
Stanislaus River to Paradise Dam	14	1.7

It is seen, therefore, that with floods controlled by the reservoirs of the State Water Plan, the degree of protection afforded against winter floods by works designed for summer flood flows, in this section of the valley, would be from more than three to about eight times greater than without reservoir control. With a slight increase in the amount of regulation on the Stanislaus River and some increase in flood channel capacity from the Stanislaus River to Paradise Dam, the same protection would be provided lands in this division as would be afforded in the other two. The degree of protection with reservoir control would be greater than that provided by the existing flood control project of the Sacramento Valley.

It has been shown in the section of this chapter on flood control plans for the San Joaquin River from the Merced River to Paradise Dam, with floods uncontrolled by reservoirs, that protection of the lands in this division of the valley against uncontrolled summer flood flows would cost about $3,500,000 and that protection against uncontrolled winter floods would cost about $5,900,000. The uncontrolled winter flood flows used for designing the works on which the cost estimate was based, however, would be exceeded less than once in 250 years on the average, whereas the works designed for summer flows would be endangered by controlled winter flows on an average of somewhat less than one to about 1.7 times in 100 years, as shown in the foregoing tabulation. No estimate has been made of the cost of works to protect the lands against uncontrolled winter floods exceeded once to 1.7 times in 100 years, on the average, but this cost probably would be very little less than that of works for floods exceeded about once in 250 years on the average. Therefore, the flood control benefit in this section of the valley from the operation of the State Water Plan under conditions of ultimate development, and with the reservoirs operated for flood control, would be almost $2,400,000.

San Joaquin Delta—It has been shown in the section of this chapter on flood control plans for the San Joaquin Delta with floods uncontrolled by reservoirs, that the maximum capacity of the present channels from Paradise Dam to the head of Middle River is about 70,000 second-feet. With floods uncontrolled by reservoirs in the San Joaquin Valley above Paradise Dam, this flow may be exceeded 21 times in 100 years on the average. If flood control were provided by the reservoirs of the State Water Plan, it may be seen from Plate LXXV that a flow of 70,000 second-feet below the confluence of the San Joaquin and Stanislaus rivers would be exceeded only seven times in 100 years on the average. This would give an increase in degree of protection for the 50,000 acres of land lying between Paradise Cut and Tom Paine Slough, between Paradise Cut and the San Joaquin and Middle rivers, and east of the San Joaquin River from Paradise Dam to and including Stockton, of three times that now provided.

It was also shown in the same section of this chapter that the delta channels between the head of Middle River and Venice Island have a present capacity of 100,000 second-feet and that below that point there is a larger capacity, especially since the dredging of the Stockton Ship Canal. If the upper 1.75 miles of Paradise Cut were improved to enable the cut to carry 60,000 second-feet and the cut were cleared below the Southern Pacific Railroad, there would be a channel capacity through the entire delta of 100,000 second-feet. Under these conditions and with floods controlled by the reservoirs of the State Water Plan, the delta lands would have protection against a flood that would be exceeded considerably less than once in 250 years on the average.

As previously stated, the estimated cost of works required to care for uncontrolled flood flows through the delta is about $10,000,000. It was also pointed out that with such works, flood plane elevations in parts of the delta would be so great that levees could not be constructed to safely provide for them. The cost of improving Paradise Cut to enable it to carry 60,000 second-feet would be relatively small and the saving in the cost of flood control works for the San Joaquin Delta, therefore, with reservoir control, would be almost $10,000,000 and the degree of protection would be much greater than with channels provided for uncontrolled flows.

Summary—Summarizing the savings in costs of works to protect the lands in the San Joaquin Valley with floods controlled by the reservoirs of the State Water Plan, over what they would cost with uncontrolled flows, the following probable minimum amounts are obtained:

Upper San Joaquin Valley south of San Joaquin River	$1,200,000
Upper and lower San Joaquin Valleys—Herndon to Merced River	4,250,000
Lower San Joaquin Valley—Merced River to Paradise Dam	2,400,000
San Joaquin Delta	10,000,000
Total	$17,850,000

This total does not include any saving in the cost of works along the Calaveras, Mokelumne and Cosumnes rivers and along Dry Creek, for which no estimates have been made.

CHAPTER X

NAVIGATION

One of the important objectives of the State Water Plan in the Great Central Valley is improvement of navigation. Within the San Joaquin River Basin, the navigable waterways comprise the main San Joaquin River, the tributary Mokelumne River and many miles of interconnecting natural and artificial channels in the San Joaquin Delta. The Sacramento River, chief navigable waterway in the Sacramento River Basin, joins the San Joaquin River in the delta and the combined streams discharge through a common mouth into Suisun Bay, which forms the easterly arm of the great harbor of San Francisco Bay. The Federal Government has recognized these streams as navigable waterways since the seventies and has exercised jurisdiction over them, through the corps of engineers of the United States War Department, in the interest of improvement and maintenance of navigation. Commanding a reach of over 250 miles and extending through the heart of the Great Central Valley from Red Bluff on the north to Mendota on the south, the Sacramento and San Joaquin rivers are actually or potentially navigable and together afford an inland waterway system of great importance and value, which, if adequately improved, would provide a medium of economical transportation for a major portion of the State, not only for local commerce but also for interstate and foreign commerce. At present commercial navigation is confined for the most part to the lower reaches of both the San Joaquin and Sacramento rivers below Stockton and Sacramento respectively. Improvement works will be required to provide dependable navigation depths for the operation of commercial craft on the upper sections of these waterways above these cities. Accordingly, in the formulation of plans for the coordinate development and utilization of the water resources of the Great Central Valley, consideration has been given to the need for water transportation and the possibilities and feasibility of further navigation improvement.

Studies with respect to navigation on the Sacramento River are presented in another report.* This chapter is devoted to a presentation of data and studies with respect to water transportation and improvement of navigation in the San Joaquin Valley, particularly on the San Joaquin River. Much of the data set forth are taken from reports of the United States Army engineers, including particularly a recent report† and other data and studies made available from subsequent investigations and studies regarding further improvement of navigation on the San Joaquin River.

History of Navigation on the San Joaquin River.

Commercial navigation on the San Joaquin River may be considered to have had its beginning with the discovery of gold in California in 1848. Although there had been some navigation on the

*Bulletin 26, "Sacramento River Basin," Division of Water Resources, 1931.

†House of Representatives Document No. 791, 71st Congress, third session, "Partial Report on the Sacramento, San Joaquin and Kern rivers, California."

river prior to that time starting with exploring expeditions as early as 1817 and continuing in later years during the Mexican regime, only small craft were operated and there was no important amount of commerce. Stockton was founded in 1847 and regular communication with San Francisco was first provided by whale boats. In September, 1848, the sailing craft "Maria" owned by Captain Weber started regular trips as a mail packet between Stockton and San Francisco.

Following the discovery of gold, the San Joaquin River and the Sacramento River, as well, assumed great importance as the main arteries of communication and transportation to and from the early settlements of California and the outside world. The depths in these streams were sufficient during most of the year for the type of vessel then used on the high seas. Passengers and freight were carried from foreign ports or from the Atlantic coast around Cape Horn or via the Isthmus of Panama to the main settlements along these rivers. In addition, a large volume of traffic sprang up between San Francisco and the inland settlements. Thousands of gold seekers rushed to the mines and it was found that the few sailing craft then in operation were inadequate for the transportation of passengers and supplies from San Francisco to the inland ports. This led to the construction of steamers for use on the San Joaquin River. One of the first steamers to navigate to Stockton is said to have been the "Merrimac" which was assembled in San Francisco after having been shipped in sections around Cape Horn. This boat was followed by numerous others, notably the "John A. Sutter" whose maiden trip was the occasion of a great celebration in Stockton.

The rate on freight in 1850 was $20 per ton and passenger fares were $18 for cabin and $12 for deck accommodations. Competition arose quickly and in 1852 one steamer reduced deck fare to $1.50 and another promptly offered to carry passengers for nothing. In April, 1852, there were seven steamers making daily trips to and from Stockton. In 1854, the California Navigation Company secured a monopoly of all navigation by either purchasing or taking into a combination every river steamer operating on the Sacramento and San Joaquin rivers. This company was absorbed by the Central Pacific Railroad in 1869 which, in that year, completed the transcontinental railroad.

Following the inrush of settlers with the discovery of gold in California, the demand for agricultural products rapidly increased and many of the early settlers started farming the rich agricultural lands in the San Joaquin and Sacramento valleys. Transportation of products and supplies from and to the farming lands in the San Joaquin Valley was for many years provided by water carriers operating on the upper San Joaquin River, starting as early as the fifties. In February, 1858, the steamer "Peytona" started on a trial trip up the San Joaquin River above Stockton but was forced to turn back at a point about twelve miles above the mouth of the Merced River due to the low stage of the river. In April of the same year, after a large increase in the stream flow, the steamer "Henrietta" proceeded to Fresno City which was then located on Fresno Slough, and maintained a regular schedule for several months. This boat, however, had a draft of only about eighteen inches. In the flood season of 1862, an attempt was made to run a stern-wheel steamer from the San Joaquin River to Tulare Lake from which water was flowing. The steamer grounded, the flood subsided and the boat was left stranded on the dry plain.

Between the years 1860 and 1870, freight to and from the San Joaquin Valley was transported on the San Joaquin River, with river craft navigating to Mendota and occasionally as far upstream as Herndon about twelve miles northwest of Fresno. About 1870, navigation above Mendota was discontinued. It was about this time also that the railroad from Stockton to Fresno was completed, thereby supplying rail transportation for the east side of the San Joaquin Valley. It was not until 1889 that the railway on the west side of the valley was built. Prior to that time the river was the only transportation outlet for that area. Hills Ferry was considered the head of navigation, although boats operated to Firebaugh about eleven miles below Mendota for a few weeks each year. Steamers continued to operate to Hills Ferry, with an occasional trip to Firebaugh until 1896. Insufficient water in the river, however, made navigation more or less seasonal. Since 1896, boats have gone as far upstream as Grayson (54 miles above Stockton) when the discharge past that point was 6000 second-feet or more, and to San Joaquin City (35 miles above Stockton) when the discharge past that point was 4000 second-feet or more.

From earliest years, navigation on the San Joaquin River above Stockton has always been seasonal in character because of the marked variability in flow of this stream. After the melting of the snows in the high Sierras, which is usually completed by mid-July, the flow in this stream is reduced to a relatively small quantity which has always been insufficient to provide navigation depths in most of the section above Stockton. The period of low stream flow normally extends for several months in the summer and fall until the storms of the succeeding winter increase the discharge to a sufficient amount for navigation. In addition to these unfavorable natural conditions, irrigation diversions on the San Joaquin River and its tributaries have still further reduced the flow during the summer months and have tended to increase the period of insufficient flow for navigation.

The effect of tidal action extends to a point a few miles above Lathrop on the San Joaquin River. From this point to Suisun Bay, the river gradient is rather flat. Mean tide level at Stockton is only about one and one-half feet above mean sea level at the lower end of San Francisco Bay. Therefore, the lower San Joaquin River and especially the portion from Stockton downstream is not greatly affected by the reduced stream flow. The river channels below Stockton are naturally rather deep and were not greatly affected by deposition of hydraulic-mining debris such as occurred along the Sacramento River. However, above Stockton and especially in the section of the San Joaquin River above Lathrop, the possibility of navigation is entirely dependent upon the magnitude of streamflow. From the railroad bridge (San Joaquin Bridge) near Lathrop to Hills Ferry, the average river gradient is about 0.8 foot per mile at low water. The average fall of the stream between Hills Ferry and Mendota is about one foot per mile and about two feet per mile from Mendota to Herndon.

Because of the naturally unfavorable condition of an insufficient stream flow to provide navigation depths during a large portion of the year on the upper San Joaquin River, navigation activities above Stockton gradually decreased until, in recent years, there has been virtually no commercial craft plying the stream above Lathrop, or for all practical purposes above Stockton. The service of the water carriers was never dependable in the upper San Joaquin River and the transportation requirements of the San Joaquin Valley naturally drifted to other agencies including first the railroads and in more recent years truck transportation as well.

Since the beginning of commercial navigation on the San Joaquin River, water transportation has flourished, especially on the section below Stockton, where adequate navigation improvements have been provided by the Federal Government. The records of tonnage and passenger movement on the San Joaquin River since 1880, compiled from the annual reports of the chief of engineers of the United States War Department, are shown in Table 207. The segregation of the

TABLE 207

WATER-BORNE TRAFFIC ON SAN JOAQUIN RIVER, 1880 TO 1929

Compiled from Annual Reports of Chief of Engineers, United States War Department

Year	Freight		Passengers	Year	Freight		Passengers
	Tons	Value			Tons	Value	
1880	305,093	----------	----------	1905	373,186	----------	----------
1881	----------	----------	----------	1906	440,300	$18,293,401	----------
1882	----------	----------	----------	1907	736,472	25,374,699	----------
1883	432,250	----------	----------	1908	509,233	21,716,334	50,000
1884	442,950	----------	----------	1909	773,945	31,275,925	110,000
1885	664,370	----------	----------	1910	631,681	32,878,108	125,000
1886	470,475	----------	----------	1911	600,128	35,768,215	100,556
1887	470,850	----------	----------	1912	632,591	38,854,539	107,687
1888	----------	----------	----------	1913	820,399	35,479,741	207,249
1889	371,200	----------	55,000	1914	772,156	36,358,240	189,667
1890	----------	----------	57,840	1915	831,234	42,179,160	213,915
1891	527,684	----------	57,840	1916	824,222	50,367,700	182,486
1892	370,000	----------	56,000	1917	1,890,856	65,204,825	206,131
1893	395,000	----------	90,000	1918	[1]766,236	65,186,292	236,379
1894	346,094	----------	154,500	1919	647,156	54,100,043	221,259
1895	401,684	----------	100,178	1920	[2]673,241	42,201,289	[3]242,238
1896	431,736	----------	61,531	1921	646,657	37,263,122	206,783
1897	454,955	----------	13,671	1922	678,751	34,291,675	188,807
1898	287,524	----------	112,039	1923[4]	697,773	38,027,909	163,566
1899	270,013	----------	64,975	1924	727,499	38,185,313	133,017
1900	270,887	----------	133,832	1925	849,687	47,192,499	131,520
1901	357,746	----------	108,637	1926	934,809	56,455,662	113,452
1902	322,000	----------	84,842	1927[5]	1,152,743	51,604,962	99,320
1903	376,883	----------	----------	1928	984,326	43,378,146	80,828
1904	360,486	----------	74,974	1929	941,139	42,759,858	77,993

[1] There were in addition 1,348,146 tons of water transported.
[2] There were in addition 19,065 tons of water transported valued at $1,922.
[3] Includes 27,075 passengers carried in ferry traffic.
[4] Subsequent to 1922 Government materials used in improvement of river are not included in tonnage.
[5] Since 1927, traffic in New York Slough which does not pass over other sections of river has been included.

amounts between the sections of the river above and below Stockton are not available. The data include all traffic on the San Joaquin River from its mouth to the present head of navigation at Hills Ferry but do not include the traffic on the Mokelumne River.

The records set forth in Table 207 show the greatest tonnage and number of passengers carried in the year 1917, which probably reflects war time conditions. However, with this exception, the records indicate a continuous and fairly steady growth of waterborne tonnage since about 1900 to a present movement of nearly 1,000,000 tons, having a value of $40,000,000 to $50,000,000. Most of this movement is on the lower river below Stockton, where adequate and dependable all-year navigation has been maintained. Over 50 individuals or companies operate freight-carrying vessels below Stockton, comprising stern-wheel steamers, motor-screw tow boats and freighters, and barges. Stern-wheel steamers are gradually being displaced by diesel equipment. The growth of water-borne traffic on this section of the river clearly evidences the demand for water transportation in the San Joaquin Valley and indicates that there would be a large amount of tonnage moved by water over the upper San Joaquin River if dependable all-year navigation were provided.

Navigation on the Mokelumne River was first accomplished by a steamboat proceeding up that river to Lockeford in April, 1862, a year of high water. Following this, navigation was maintained to Woodbridge and occasionally to Lockeford. In 1865, the Mokelumne River Improvement Company was organized under an act of the State Legislature. They were entitled to collect a tax of ten cents per ton for twenty years for clearing the river from Georgiana Slough to Athearns Bridge, but long before the twenty years had expired conditions had so changed that there was no freight on which the tax could be collected. Navigation on the Mokelumne River has been improved and maintained to some extent by the Federal Government since 1882, but only a relatively small amount of about $50,000 has been expended for improvement and maintenance in the lower channels between its mouth and the Galt-New Hope Bridge. Tidal action extends throughout most of this improved section. The records in the annual reports of the chief of engineers of the United States War Department show an annual movement since 1926 of 70,000 to 80,000 tons, having a normal value of from $5,000,000 to $6,000,000.

Existing Navigation Project on San Joaquin River.

Navigation improvements on the San Joaquin River were initiated by acts of Congress starting in 1876 and continued under modifications of subsequent acts up to the act creating the latest approved project passed on January 27, 1927. The acts of August 14, 1876, March 3, 1881, July 5, 1884, August 11, 1888, July 13, 1892, August 18, 1894, and June 3, 1896, provided for cutting off sharp bends and making cut-offs below the mouth of Stockton Channel, dredging Mormon Slough, constructing wing dams in the river between Stockton and Hills Ferry without adopting any specific channel dimensions; the act of June 25, 1910, provided for a 9-foot channel up to Stockton (H. Doc. No. 1124, 60th Cong., 2d sess.); the act of July 25, 1912, provided for the improvement of Fremont Channel and McLeod Lake (H. Doc. No. 581, 62d Cong., 2d sess.); and the act approved January 21, 1927, provided for the 26-foot project (H. Doc. No. 554, 68th Cong. 2d sess.).

The existing project, as outlined in House Doc. No. 791, previously cited, provides for a channel 26 feet* deep at mean lower low water and 100 feet wide at the bottom (except in New York Slough, where the

*The 26-foot depth provided under the existing project for the Stockton Ship Canal has recently (1933) been increased to a depth of 30 feet under a modification in plans approved by the Chief of Engineers of the U. S. War Department.

width is to be 300 feet), from the mouth of New York Slough to the city of Stockton, a distance of 45 miles, with suitable passing places and a turning basin at Stockton; for dredging Mormon Slough to a depth of 9 feet for a distance of 1.7 miles above its mouth; for a depth of 9 feet at mean lower low water in Fremont Channel and McLeod Lake; for cutting off sharp bends, making cut-offs and closing side channels in the river; and for snagging, removing overhanging trees, and constructing wing dams from Stockton Chanel to Hills Ferry, 86 miles, to facilitate light-draft navigation on this part of the river during higher stages of water.

According to information made available by the Division Engineer of the Pacific Division, United States War Department, the total cost of work on the San Joaquin River to June 30, 1930, was $1,272,101.69 of which $579,586.53, including $56,606.85 contributed funds, was for new work and $692,515.16 for maintenance. The estimated cost for new work revised in 1927 is $4,046,400, of which local interests are to contribute $1,307,500. The latest approved estimate of annual cost of maintenance is $181,000 during the first year and $111,000 thereafter. In addition, the entire expense of right of way and terminal facilities for the Stockton Ship Canal is to be borne by the city of Stockton. It is reported that an expenditure of some $3,000,000 will be involved for these purposes.

Present Limits of Navigation on San Joaquin River.

Under present conditions, navigation on the San Joaquin River is virtually limited to the section below Stockton. This section is now being improved to a depth of 26 feet to accommodate ocean-going vessels, thus adding Stockton as a port to the San Francisco Bay harbor. It is estimated by the United States War Department that the entire 26-foot project will be completed early in 1933. Above Stockton, navigation conditions are fair for most of the year as far as the San Joaquin Bridge near the town of Lathrop or within the limits of tidal action on this stream. Above tidal action, south of the San Joaquin Bridge, navigation is not practicable during low stages of the river. It is stated by the Division Engineer that there is usually a depth of six feet in the river between Stockton and Hills Ferry from April to June. Although the flow in the river has been diminished to some extent by irrigation diversions in recent years, conditions as to navigability are not very much different than in former years before the growth in irrigation development. The lack of dependable navigation depths has discouraged shipment of freight by water and there has been no commercial navigation of importance for many years on the San Joaquin River above Stockton.

Economic Value of Further Improvement of Navigation on the San Joaquin River.

The San Joaquin River from its mouth to Mendota offers a potential inland waterway through the heart of the San Joaquin Valley which, if adequately improved, would provide a means of cheap water transportation for the large and increasing volume of tonnage moving to and from the San Joaquin Valley and San Francisco Bay points and other states and foreign nations as well. The improved portion of the river from Stockton to its mouth is already functioning as one of the most important and successful internal waterways in the Nation. The demand for cheap water transportation on the lower improved section of this stream indicates that a large amount of tonnage would be moved by water over the upper San Joaquin River if it were adequately improved to provide dependable all-year navigation. It appears that cheap water transportation would be of great value to the future economic welfare of the San Joaquin Valley.

The navigable portion of the upper San Joaquin River is paralleled on both sides by the Southern Pacific Railroad and on the east side by The Atchison, Topeka & Santa Fe Railroad. Motor trucks operate on a network of improved highways. Hence, water transportation on the upper San Joaquin River would be subject to competition with railroads and motor trucks.

Based upon data made available by the Division Engineer of the Pacific Division, United States War Department, the present tonnage movement to and from the area which would be tributary to an improved waterway on the upper San Joaquin River from Stockton to Mendota aggregates 927,000 tons annually. This represents the estimated tonnage moving by truck and rail, parallel to the waterway, to and from six counties in the San Joaquin Valley, comprising Stanislaus, Merced, Madera, Fresno, Tulare and Kings. Of this total estimated present tonnage movement, the Division Engineer considers that the movement to and from Stanislaus County probably would not go by water because it could be hauled more cheaply directly to and from the port of Stockton. Based upon a study of comparative rail, truck and water rates and tonnage movement, the Division Engineer estimates that, of the total present tonnage to and from the remaining five counties, nearly 60 per cent could be moved by water over an improved upper San Joaquin River channel at an average saving of about 55 cents per ton considering all movement to and from the port of Stockton.

From studies made of past growth and possibilities of future development in the San Joaquin Valley, the Division Engineer estimates that the tonnage movement to and from the San Joaquin Valley tributary to an improved waterway will triple in 50 years and double in 25 years. On this basis, the Division Engineer estimates that the average annual prospective tonnage during the next 50 years to and from the tributary area of an improved upper San Joaquin River channel, excluding Stanislaus County, would be twice the present tonnage or 1,530,000 tons; and that of this total 40 per cent would move over an improved waterway at an average saving of 55 cents per ton or a total annual saving of $335,000. Deducting the cost of maintenance and operation, estimated as subsequently shown at $110,000, the net annual saving would be $225,000. Capitalizing this net saving at four per cent, the Division Engineer estimates the economic value of improving the upper San Joaquin River from Stockton to Mendota at $5,625,000.

Although no detailed study has been made by this division for this report of the economic value of further improvement of navigation on the San Joaquin River, it is believed that a more comprehensive study of present and future tonnage movement than that made by the Division Engineer of the War Department would show a considerably greater tonnage for actual movement by water than that estimated.

Moreover, it is believed that a greater average saving per ton than that estimated by the Division Engineer could be effected by water transportation. As a further consideration, it would appear proper that the economic value of savings in transportation costs by water for the entire San Joaquin River from its mouth to Mendota should be compared with the cost of improving the entire waterway rather than comparing the benefit values with the cost of improvement separately for each section of the waterway above and below Stockton. It is believed that such a comparison would show that the benefit values from savings in transportation costs for the entire waterway considered as a single improvement and economic unit would be considerably in excess of the cost of complete improvement from the mouth to the head of navigation at Mendota. In addition to the direct savings in transportation costs for tonnage actually moving by water, there would also be savings in transportation costs on tonnage moving by rail or truck effected through the reduction of rail and truck rates to meet water competition. It is believed that the benefit value of such savings should be credited to the waterway. With such modification in the methods for estimating the economic value of further improvement on the San Joaquin River, it appears probable that the benefit values which could be reasonably anticipated would be more than sufficient to justify the expenditure required for providing dependable navigation from Stockton to Mendota in accord with the proposed plan of canalization subsequently presented.

Proposed Plan for Further Improvement of Navigation on the San Joaquin River.

In accord with the investigation made by the United States War Department, the portion of the San Joaquin River which is worthy of consideration with a view to further improvement in the interest of navigation lies between Stockton and Mendota. It is stated that above Mendota the characteristics of the river are so unfavorable to improvement that manifestly the cost would be greater than the value of the benefits reasonably to be expected.

The following description of the proposed plan and estimates of cost for navigation improvement are taken from data made available by the Division Engineer of the Pacific Division, United States War Department. The plan of improvement recommended provides for the canalization of the river from Stockton to Mendota. This is considered to be the only practicable plan of improvement for this section of the river. It is proposed to provide a minimum navigation depth of six feet. This would require the construction of 13 movable dams equipped with locks with lifts varying from 9 feet to 18 feet and averaging about 13 feet. Locks are proposed with dimensions of 45 by 300 feet in the clear.

In the stretch from the mouth of Stockton Channel to Hills Ferry Bridge, a distance of 85.9 miles by the existing river channel, 5 locks and dams will be required with an aggregate lift of 63 feet. Fourteen cut-offs will be desirable, which in conjunction with the widening of certain sloughs will effect a reduction of 20.6 miles in the present river channel distance for this section.

In the stretch from Hills Ferry Bridge to Mendota Dam, a distance of 88.2 miles by the existing river channel, 8 locks and dams will be required with an aggregate lift of 88.4 feet. In this stretch 21 cut-offs will be desirable, which will effect a reduction of 10.2 miles in the present distance by river for this section.

In addition to the locks, dams and cut-offs, levees are proposed at the lower ends of pools and some excavation near the upper ends. The cost of improvement by canalization, as estimated by the Division Engineer, including levees and excavation as required for navigation only, is shown in Table 208.

TABLE 208

CAPITAL COST OF DAMS AND LOCKS FOR CANALIZATION OF SAN JOAQUIN RIVER FROM STOCKTON TO MENDOTA

Estimate by Division Engineer, Pacific Division, U. S. War Department

Section of river	Distance via improved channel, in miles	Number of lifts	Total lift, in feet	Capital cost		
				Locks	Project less locks*	Total
Stockton Channel to Hills Ferry Bridge	65.3	5	63.0	$2,500,000	$2,000,000	$4,500,000
Hills Ferry Bridge to Mendota Dam	78.0	8	88.4	3,500,000	4,000,000	7,500,000
Totals	143.3	13	151.4	$6,000,000	$6,000,000	$12,000,000

* Includes dams, levees, spillways, channel excavation, right of ways, drainage, etc.

The Division Engineer's estimate of annual cost of maintenance and operation of the locks and dams, including dredging in the pools but excluding maintenance of levees, is $110,000.

It will be noted that the Division Engineer's estimate of the economic value of improvement is slightly less than the estimated cost of the locks alone for the proposed plan of canalization. However, as previously stated, it is believed that the benefits in transportation savings effected by the proposed improvement would show an economic value considerably greater than estimated by the Division Engineer and probably would be sufficient in amount to justify the entire expenditure required of $12,000,000 for dams, locks and appurtenant works.

Coordination of Proposed Plan for Navigation Improvement on San Joaquin River With State Water Plan for San Joaquin River Pumping System.

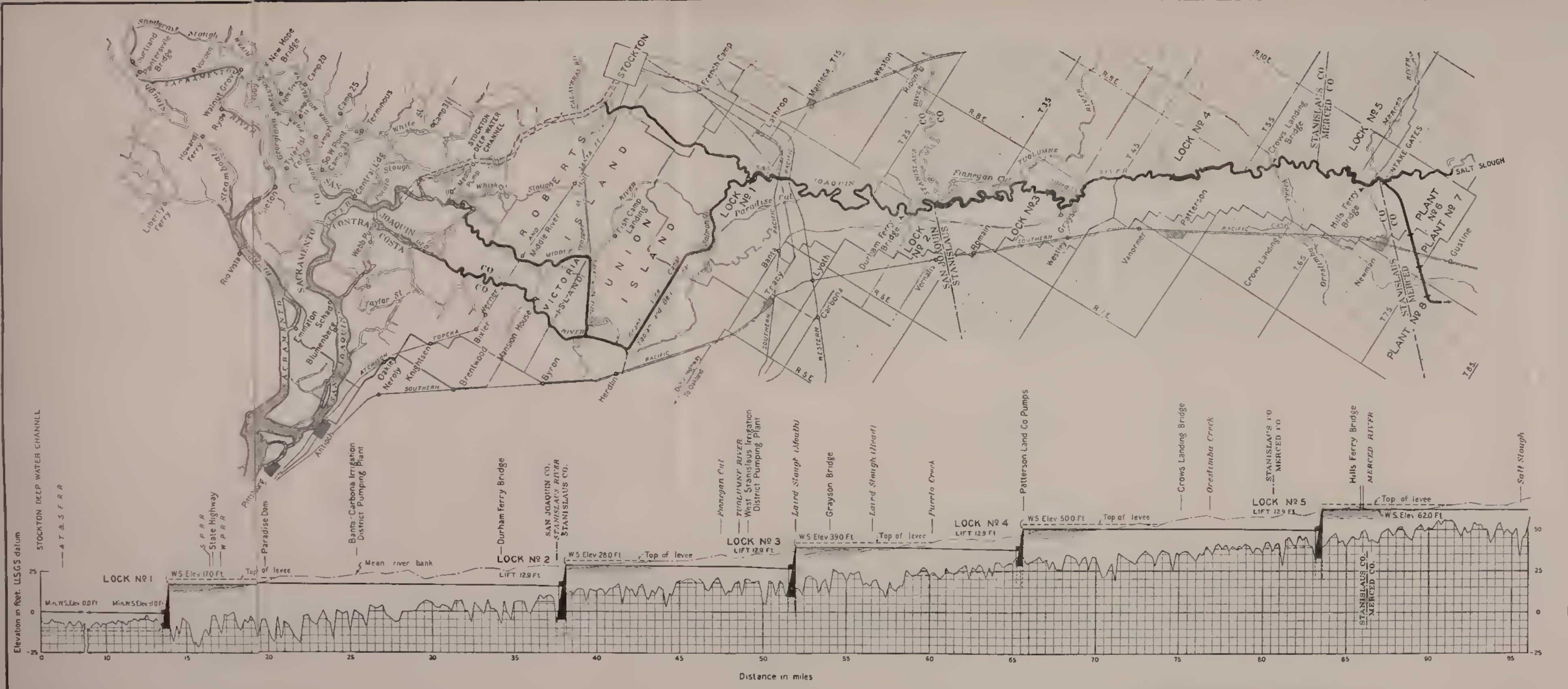
In accord with the State Water Plan for the San Joaquin River Basin, the San Joaquin River Pumping System is proposed as one of the major conveyance units to transport water from the Sacramento-San Joaquin Delta channels to Mendota. The plan for this conveyance unit is set forth in detail in Chapter VIII. From the delta to the mouth of the Merced River (approximately at Hills Ferry) it provides for a system of dams and pumping plants for conveying the water up the river channel, lifting the water to an elevation of 62 feet (United States Geological Survey datum). From this point the proposed pumping system departs westerly from the river through a constructed canal extending to Mendota. The proposed plan for the pumping system was selected as being the most economical after careful consideration of numerous alternate plans and routes of which seven are presented in detail in Chapter VIII, including one plan which would utilize the river channel through its entire length from the delta to Mendota with a system of dams and pumping lifts in the river channel. The plan as proposed would canalize the river from the delta to Salt Slough, nine miles above the mouth of Merced River. If the dams were equipped with locks, slack water navigation would be provided to Salt Slough. The location of these dams as proposed in the San Joaquin River Pumping System differs to some extent with the plan as proposed by the United States War Department. However, the canalization effected would provide a minimum depth of six feet for navigation from Stockton to Salt Slough and would be equivalent to the plan outlined by the Army Engineers for this section of the river. A plan and profile, showing the canalization of this lower section of the San Joaquin River which would be effected in conjunction with the San Joaquin River Pumping System, are presented on Plate LXXVII, "Canalization of San Joaquin River in Conjunction with San Joaquin River Pumping System, Stockton Deep Water Channel to Salt Slough."

With a concrete lined canal in the upper portion of the selected plan for the San Joaquin River Pumping System, the capital and annual costs are only slightly less than the alternate all-river channel route. The estimates of capital and annual costs for this unit have been based on construction of a concrete lined canal in this upper section. However, it is entirely possible that final designs and studies for this unit would show that a large part of the concrete lining could be omitted and thus materially decrease the capital and annual costs of the adopted plan and route, with resulting costs substantially less than those for the all-river channel route. Therefore, the final consideration of the most desirable plan and route to adopt for the San Joaquin River Pumping System will depend largely upon the need and benefit values of navigation improvement on the San Joaquin River to Mendota and particularly upon the expenditures which would be justified by the Federal Government in the interest of further improvement of navigation. The Division Engineer's estimate of economic value of navigation improvement, as previously set forth, indicates that the Federal Government would be justified in constructing the necessary locks for all dams in a combined pumping and canalization project. As previously stated, it is believed that the benefit values for improvement of navigation would be greater than estimated by the Division Engineer. It appears probable that expenditures by the Federal Government in the interest of navigation would be justified by the benefit values, not only for the construction of the necessary locks in the dams but also for a portion and perhaps all of the cost of the dams required to effect canalization. The most desirable plan would be one which would combine and coordinate the works required for conveyance of water and for improvement of navigation in the entire section of the river from Stockton to Mendota. If sufficient funds are made available in the interest of navigation to pay for the cost of the locks and a portion of the dams for a combined canalization and conveyance project on the San Joaquin River from Stockton to Mendota, the all-river channel route for the San Joaquin River Pumping System would be the most advantageous plan for adoption.


Note:
For design of typical dam, lock and pumping plant see Plate XL.
50
25
0
-25
GENERAL PLAN AND PROFILE
SHOWING
CANALIZATION OF SAN JOAQUIN RIVER
IN CONJUNCTION WITH SAN JOAQUIN RIVER PUMPING SYSTEM
STOCKTON DEEP WATER CHANNEL TO SALT SLOUGH
SCALE OF MILES
0 2 4 6

sideration of numerous alternate plans and routes of which seven are presented in detail in Chapter VIII, including one plan which would utilize the river channel through its entire length from the delta to Mendota with a system of dams and pumping lifts in the river channel. The plan as proposed would canalize the river from the delta to Salt Slough, nine miles above the mouth of Merced River. If the dams were equipped with locks, slack water navigation would be provided to Salt Slough. The location of these dams as proposed in the San Joaquin River Pumping System differs to some extent with the plan as proposed by the United States War Department. However, the canalization effected would provide a minimum depth of six feet for navigation from Stockton to Salt Slough and would be equivalent to the plan outlined by the Army Engineers for this section of the river. A plan and profile, showing the canalization of this lower section of the San Joaquin River which would be effected in conjunction with the San Joaquin River Pumping System, are presented on Plate LXXVII, "Canalization of San Joaquin River in Conjunction with San Joaquin River Pumping System, Stockton Deep Water Channel to Salt Slough."

With a concrete lined canal in the upper portion of the selected plan for the San Joaquin River Pumping System, the capital and annual costs are only slightly less than the alternate all-river channel route. The estimates of capital and annual costs for this unit have been based on construction of a concrete lined canal in this upper section. However, it is entirely possible that final designs and studies for this unit would show that a large part of the concrete lining could be omitted and thus materially decrease the capital and annual costs of the adopted plan and route, with resulting costs substantially less than those for the all-river channel route. Therefore, the final consideration of the most desirable plan and route to adopt for the San Joaquin River Pumping System will depend largely upon the need and benefit values of navigation improvement on the San Joaquin River to Mendota and particularly upon the expenditures which would be justified by the Federal Government in the interest of further improvement of navigation. The Division Engineer's estimate of economic value of navigation improvement, as previously set forth, indicates that the Federal Government would be justified in constructing the necessary locks for all dams in a combined pumping and canalization project. As previously stated, it is believed that the benefit values for improvement of navigation would be greater than estimated by the Division Engineer. It appears probable that expenditures by the Federal Government in the interest of navigation would be justified by the benefit values, not only for the construction of the necessary locks in the dams but also for a portion and perhaps all of the cost of the dams required to effect canalization. The most desirable plan would be one which would combine and coordinate the works required for conveyance of water and for improvement of navigation in the entire section of the river from Stockton to Mendota. If sufficient funds are made available in the interest of navigation to pay for the cost of the locks and a portion of the dams for a combined canalization and conveyance project on the San Joaquin River from Stockton to Mendota, the all-river channel route for the San Joaquin River Pumping System would be the most advantageous plan for adoption.



Note
For design of typical dam lock and pumping plant see Plate XL

GENERAL PLAN AND PROFILE
SHOWING
CANALIZATION OF SAN JOAQUIN RIVER
IN CONJUNCTION WITH SAN JOAQUIN RIVER PUMPING SYSTEM
STOCKTON DEEP WATER CHANNEL TO SALT SLOUGH

SCALE OF MILES

APPENDIX A

CLASSIFICATION OF VALLEY FLOOR LANDS IN SAN JOAQUIN RIVER BASIN

By

S. T. Harding

Consulting Engineer

December, 1930

TABLE OF CONTENTS

CLASSIFICATION OF VALLEY FLOOR LANDS IN SAN JOAQUIN RIVER BASIN

The following discussion of lands in the San Joaquin Valley pertains only to the main area of the valley floor. The field work on the adjacent plains and foothill areas to the east, from the San Joaquin River northward was handled under different supervision and standards of classification and is not included. The same colors are used on the map showing the land classification to indicate like numbered classes of lands in the valley and foothill areas. The division between the two areas is discussed in the description of the local areas. In general, the plains and foothills extend into the eastern portions of Hydrographic Divisions 8, 9 and 11 delineated on Plate VI and incorporated in Chapter III of this bulletin.

The area described herein extends from the southern end of the valley northward to the southern boundary of Hydrographic Divisions 10 and 12. It includes the principal agricultural areas in the eight main counties of the San Joaquin Valley. The resulting classification is shown on Plate V included in Chapter III of this bulletin. The resulting areas of each class, together with the areas of included foothill lands, also are shown in the tables of land classification in Chapter III.

The classification described herein embodies the results of various investigations by the State Engineer in the San Joaquin Valley during the last ten years. Several of these investigations have related to the areas to be included and the feasibility of proposed irrigation districts in connection with proceedings before the State Engineer in relation to their organization or financing procedure. Areas so included were reviewed and other areas have been examined in making this classification. The actual field work for this report was done by the writer in the areas south of the San Joaquin River and the area in the six northern irrigation districts on the east side of the valley, and by Harry Barnes for the remainder of the area, including principally lands in Madera County and along the San Joaquin River.

The results of the field work were submitted to the San Joaquin Valley Water Committee, representing the eight valley counties, and by them referred to the sub-committee for each county. These committees accepted the resulting classification with minor exceptions. C. H. Holley made a comprehensive and independent classification of the lands in Tulare County and some adjacent areas, partly for the Tulare County Committee and partly for the State Engineer. The results were in general agreement with those presented herein.

Any study of irrigation development in this area, either for present construction or for future ultimate plans, requires a consideration of the quality of the land. It is recognized by everyone that lands of all qualities, varying from the very best to the hopelessly poor, occur in the San Joaquin Valley. It is essential that the extent and location of the different classes be known in preparing plans for the possible service of lands of satisfactory quality, and also, so that lands not able to meet costs for irrigation may be excluded. While land classification is necessarily to some extent a matter of judgment, it is essential that a uniform standard be applied to the whole area. The present classification was planned to meet these requirements.

Basis of Classification.

A classification of land in relation to irrigation is more than a soil survey. Irrigability involves soil texture, alkali and roughness, as well as the cost of water delivery. The value of land for irrigation is the composite result of all of its physical factors. For practical application it is necessary to limit the results to a few classes. Each of such classes includes a zone of quality rather than a single grade of land usefulness.

Five classes of land were used in the field work on which this report is based. Their basis was established prior to the field work and maintained. Boundaries between the classes were located on field maps on a scale of two inches per mile. The quadrangle sheets of the U. S. Geological Survey were used where available. Full use also was made of the Reconnaissance Soil Survey maps of the U. S. Bureau of Soils. Field notes were placed directly on the field maps. To indicate the basis for the rating, a system of letters was used to show the causes for reduced rating. These consisted of "a" to indicate hardpan, "b" for alkali, "c" for channel cut areas near streams, "d" for general roughness, and "e" for generally poor fertility. As the smaller scale of the land classification map does not permit showing these distinctions, the reason for reduced ratings is stated in general terms in the descriptions of the local areas.

Class 1 Lands—Class 1 has been used to designate lands of good quality which do not have any defects that materially reduce their value under irrigation. They are good lands capable of good yields at low or moderate costs of preparation for irrigation. Alkali, roughness or hardpan may be present, but not to a sufficient extent to limit the feasibility of their irrigation. All soil textures may be included, except where the texture reduces yields or increases costs so as to reduce the value of the land under irrigation.

Class 1 includes the best lands in the valley. It represents a zone of quality, however, rather than merely the very best land. Some areas of poorer Class 1 land were indicated on the field sheets as Class 1 minus. This land is shown on the smaller scale of the classification map as Class 1, however.

Lands rated as Class 1 represent areas where the quality of the land will not be a limiting factor in the feasibility of irrigation. The limit of feasible costs will be the general one set by crop values in relation to costs for lands that can produce normal average yields at low to moderate costs of preparation.

Class 2 Lands—As the name implies, these are second grade lands. They are fairly good areas in which some factor either increases the cost of preparation for irrigation so that settlement of new lands would be delayed, or decreases the crop yields so as to reduce the ability to meet irrigation costs to a material extent. Class 2 lands may be profitable to irrigate under favorable cost conditions and many of the Class 2 areas are now being irrigated under canals having rights in local streams or by pumping from wells. While no exact standard of division can be used, Class 2 lands represent areas grading down from lands which might meet two-thirds as large a cost for irrigation as adjacent areas of Class 1 lands, to those approaching Class 3.

Class 3 Lands—Class 3 was used for lands of poorer quality than Class 2. Some of this land can not now meet the usual charges for water from even local sources, and offers little prospect of being able to meet such costs under any probable forecast of conditions that may arise in the future, but with changes in economic or other factors, their use eventually may be feasible.

Class 3 lands, as classified in this work, should all be excluded from any plans for irrigation. It may be that ultimately something can be done with them, but the small prospect of this and the long time before it may occur do not justify present expenditures on their account. While it is very doubtful if Class 3 lands ever will justify irrigation, except with water at very low cost, they represent areas where the uncertainties regarding the future justify a higher rating than the nonirrigable lands of Class 5.

Class 4 Lands—Class 4 was used in this work to cover a local crop practice, as well as soil properties. These are the flooded pastures or so-called grass lands. There are large areas now flooded with surplus waters for such pasturage as may be obtainable where the quality of the land does not justify attempts at cultivated crops. Due to such flooding, a rating as nonirrigable is not justified; neither would a rating indicating the land to be suited for irrigation of ordinary crops be applicable. The Class 4 rating has been used also for lands not now flooded for pasture, but of similar quality and suitable for such flooding if water at very low cost were available. The Class 4 lands occur mainly along the San Joaquin River where such flooding is an extensive practice.

The value of such use of the grass lands is quite small. The usual condition is that of swamping at times of plentiful water supply rather than periodic applications. As the amount of water used is large in relation to the returns, such lands are suited only to localities having surplus flood waters not needed for higher types of use. These lands are generally alkaline and unproductive in general crops. Except to some extent for rice, Class 4 lands if rated for general crops would be mainly Class 5 with some Class 3. Class 4 lands are necessarily smooth enough for flooding as the value of their use will not justify leveling.

Class 5 Lands—Class 5 has been used for lands of such poor quality that the probability of any future use is regarded as too remote to justify consideration. It represents lands permanently nonirrigable as far as may be foreseen at this time. They should not be considered for irrigation service in any plans for irrigation. There may be an occasional spot of somewhat better land included in Class 5 areas, but such spots are too small, few or scattered to justify their segregation for irrigation. Class 5 land is now mainly used, to such extent as it is used at all, for dry pasture.

Factors Affecting Classification.

The value of land under irrigation is affected by soil texture, alkali, hardpan, roughness and fertility. The variations in these factors for the lands in the San Joaquin Valley, with their effect on the resulting classification, are discussed for the valley as a whole, followed by description of the general conditions in local areas.

Soil Texture—In general the San Joaquin Valley is surrounded by rough and stony areas that are nonagricultural. Adjacent to and below these areas disintegration has occurred to a sufficient depth to result in soils of residual type. Below these are old valley filling materials which have been modified in place. While these old valley filling materials have adequate general depth, hardpan is widely distributed in several of the soil series. Below and in some cases across the old valley filling soils are the recent alluvial types which extend along the tributary stream channels to the valley trough. In the valley trough the soils in the lower areas are generally heavier textured alluviums deposited under submergence or semisubmergence. These soils are partly old valley filling material and partly recent alluvial soils. There also are some areas of wind laid materials.

The areas covered in this field work are included in the three reconnaissance soil survey reports on the San Joaquin Valley by the U. S. Bureau of Soils and the California Agricultural Experiment Station. These reports and maps were utilized in this classification as the basis of soil texture. The following comments on soil types are based very largely on the U. S. Soil Survey.

Residual soils are generally unimportant in the areas covered in the present classification. This is due to their roughness and steepness, as well as to their shallow depth. For the small mean annual rainfall in the San Joaquin Valley, the residual soils have not disintegrated to a sufficient depth to form Class 1 land. Where conditions in local areas were considered to justify it some residual soils on the east side of the valley have been rated as high as Class 2. There are some similar residual soils rated as high as Class 2 on the west side. However, the main intrusions of residual soil into the valley, such as Kettleman Hills, were rated as Class 3 or 5 because of roughness.

The old valley filling soils represent the largest area of any general type of irrigable lands in the San Joaquin Valley. These soils are derived from unconsolidated water laid deposits, which have been subject to change since their deposition due to weathering, leaching and translocation of materials.

Of the several series of old valley filling soils, shown on the U. S. Soil Map, two—the San Joaquin and Madera series—are underlaid by the red or iron cemented types of hardpan. This hardpan in its typical form does not disintegrate under irrigation and is an important factor in root and moisture penetration. If broken, it does not recement. For dry farming, it may be an aid in retaining moisture, for irrigation it retards percolation and limits root penetration. It may be continuous or irregular and may be underlaid by soil or other rock. It may occur as thin strata easily broken by subsoiling or as thick masses impractical of removal. Blasting for trees has been practiced in many areas. This type of hardpan land covers extensive areas on the east side of the valley from Tulare County north. Much of the present orchard and vineyard development is on these lands. For the smoother areas with hardpan not too close to the surface or too thick to prevent good crop results, many areas were rated Class 1. Other areas were rated as Class 2 or 3, depending on the character of the hardpan. A somewhat more liberal rating was used for developed areas where the cost of preparation of the land had been incurred, than for areas where the expense of such work would retard settlement.

The Fresno series of old valley filling soils contains a compact silty subsoil equivalent to a hardpan. This is an extensively distributed soil and occurs on many well developed areas. This hardpan being silty and calcareous, blasting and subsoiling are not permanently effective in breaking it. It is generally not as continuous as that of the red type. The Fresno soils frequently contain alkali which reduces their rating. Where free from alkali these soils, except for some of the sandier areas, generally rate as Class 1.

There are other series of old valley filling soils, which do not contain hardpan extensively and are usually free from alkali. These are more extensive on the east side of the southern part of the valley. These rate Class 1 unless rough.

Some of the soils in the valley trough, which have not been modified by recent deposits of alluvium, are also classed as old valley filling types. These are usually fairly heavy in texture. Their quality varies with the extent of former submergence. The frequently submerged areas are generally of better quality with less alkali.

The Soil Survey uses the term "recent alluvial" to describe soils derived from recent stream deposits that have undergone little, if any, change by weathering since they were laid down. They occur on the areas affected by the present or recent channels of the principal streams. The Panoche series covers most of the west side plains area. These are derived from erosion in the Coast Range. The Hanford series are derived mainly from granitic rocks and vary from sands to sandy loams. Where well drained and free from alkali they are among the best soils in the valley.

In addition to the types described above, there are some areas of wind laid and lake laid materials.

Crop Adaptability—There are some lands of poorer quality for which it is difficult to assign any single defect. These lands may produce a good crop for a short period, but are unable to maintain good yields. A separate suffix was used on the field maps to indicate this condition where it resulted in lower ratings. Such lands are usually excessively sandy or have inert subsoils. Many of the more sandy soils are rated below Class 1 because of roughness, rather than general texture. General infertility was used to reduce some areas to Class 2.

Crop adaptability, as affected by climatic conditions, affects the value of land for irrigation. Such climatic factors as frost hazard are preferably rated separately from the quality of the land. A somewhat more liberal rating for roughness or hardpan was used in some areas suitable for citrus as the cost of leveling would be a less important item in such areas. Somewhat rougher lands were rated as Class 1 in areas where furrow crops, such as orchards, are to be anticipated, than in areas where flooded crops would probably be grown. The differences allowed were small, however.

Similarly, liability of overflow was not used as a factor in rating the land itself. Prevention of such overflow in such areas represents part of the cost of development to be considered with the cost of its water supply for irrigation.

Alkali—Alkali is widely distributed in the San Joaquin Valley. It occurs in amounts varying from slight to very heavy concentrations. In many areas the lines of demarcation along the boundaries of alkali areas are definite and easily located in the field. In other areas the quality of the land changes slowly and the divisions are difficult to make.

Continuous alkali is less difficult to classify. However, in many areas the alkali is spotted. Fields in which good crops may be grown on much of the area are to be found, with spots on which little or no yield can be obtained, so intermingled that detail classification is not practicable. For such areas average ratings were used.

Lands have become alkaline from both natural and artificial causes. Lower lands along streams are frequently alkaline from naturally high ground water or overflow. Other areas have become alkaline due to the rise of ground water resulting from irrigation. Ground water conditions change and this changes alkali conditions. Recent changes have generally been toward a lowering of the ground water and an improvement in alkali conditions. Methods of neutralizing or removing alkali also are being improved. These conditions make it difficult to rate alkali lands where long periods may elapse before the purposes of the classification are accomplished. The following general basis was used in this work:

1. It is not considered probable that additional areas will become alkaline. Extensive pumping is controlling and will continue to control the ground water and additional water logged areas need not be feared.
2. Lands heavily alkaline from natural causes prior to irrigation have not been reclaimed and can not be expected to be reclaimed by any practical means now in prospect.
3. Lands which have become alkaline due to irrigation may be restored by drainage, leaching, cropping or other treatment. Such restoration will be slow and expensive where the injury has been extensive. It will be difficult on lands having impervious strata interfering with leaching. Such lands do not justify any higher rating than those naturally alkaline.
4. Lands injured by alkali from irrigation, which are free from hardpan or other impervious subsoils and where the alkali is not large in amount, may be gradually restored by the maintenance of a lowered water table and proper soil treatment. The time required and cost, however, will not justify a high rating on such lands. Improvements in ground water conditions and in methods of alkali treatment will not justify rating alkali lands much higher than their present condition, but have been used to place some Class 2 lands in Class 1 minus and some better

present Class 3 lands in Class 2. The ratings used on Class 2 alkali lands in this work are considered to be as liberal as can be justified. Such lands are not suitable for inclusion in projects of high irrigation cost. Alkali removal represents a present expense for removal and a continuous loss in crop return over several years while production is being restored to normal. While the present status of alkali reclamation may justify some hopes for such ultimate restoration, such reclamation will be slow and expensive and lands now alkali can be given only limited recognition for such prospects.

Roughness—There are several kinds of roughness that affect the quality of land in this area. Along the overflow channels of the larger streams are lands that are channel cut to a sufficient extent to affect the cultivable area. The smoother portions may rate Class 1, but there may be enough lost area to justify an average rating of Class 2.

There are also extensive areas of "hog wallow" land. This term is applied to lands having hummocks and depressions with difference in elevation two to four feet spaced 25 to 50 feet apart. The size, spacing and height vary. Such lands occur mainly on the older valley filling soils underlaid by hardpan. Where the general area is smooth the leveling of "hog wallows" alone is not difficult. Much of the hog wallow land is also rolling and with shallow hardpan which interferes with leveling. Hog wallows alone would not materially reduce the rating of the land but in combination with rolling topography and hardpan they result in many areas of Class 2. Such rating was used for undeveloped lands where the costs of preparation for irrigation would retard development.

General roughness is found in areas along the sides of the valley. Reduced ratings for roughness were used where the cost of leveling would be excessive or where the general topography would require adapting the distribution of water to the land with resulting irregular areas and higher costs for application. The area covered in this work did not include much land of steep slope, except for included hill areas such as Kettleman Hills. Usually the steeper lands also are rough and shallow so that the reduced rating is due to a combination of factors. Such hill areas generally rate in Class 3 or 5.

Description of Lands by Local Areas.

The application of the standards of classification used can best be described by local areas. In the other portions of the water resources investigations the valley areas have been divided into hydrographic divisions. These are shown on Plate VI and have been used as the basis for the following descriptions. The hydrographic divisions are numbered from the south to the north.

Hydrographic Division 1—The area of Hydrographic Division No. 1 agrees with the part of Kern County in the San Joaquin Valley, except that the north three miles of the county is in Division No. 2.

Division No. 1 includes a wide variety of soils. On the east side the area of generally tertiary formation results in a zone of rolling, soil-covered hills before the rough and rocky land is reached. Residual soils occupy the higher areas. There are old valley filling soils on the higher valley lands with recent alluvial types on the stream deltas. The trough lands extending northward from Buena Vista Slough are older sedimentary soils. In general, there is less hardpan land than in the counties to the north. Alkali is widely distributed.

On the east side, north of Kern River and above present canals, the soils are free from hardpan and alkali. Much of the area would make good orchard land. For such use the rolling topography would not be as disadvantageous as for field crops. There is no definite topographic basis for fixing the upper line of the irrigable area. The area covered in this work probably goes higher than necessary for practical uses. Class 1 was used until roughness reduced the quality to Class 2. The areas under the present canals and under pumping plants near Shafter, Wasco and McFarland consist of a large body of good land fully justifying a Class 1 rating. Present development extends westward to the beginning of alkali soils.

Between the Class 1 land on the east and the lands along Buena Vista Slough is a wide area of poor land. This includes Buttonwillow and Semitropic ridges. Numerous efforts at irrigation from wells have been made, and many abandoned farms occur. Nearer the better lands on the east a generally narrow strip was rated as Class 2. The remainder was generally rated as Classes 3 and 5 as shown on the land classification map. This area does not justify consideration for irrigation. Along Goose Lake Slough are some better areas, but none justify a Class 1 rating.

The trough lands extending northwestward from Buena Vista Lake are rated Class 1 at the south with decreasing quality toward the north. The trough lands suited to irrigation are south of Wasco Road, except for a small area of Class 2 land near the north line of the division, which is within the area affected by Tulare Lake.

The west side plains consist of Panoche soil series. This is all rated as Class 1, except where roughness requires a lower rating.

The recent alluvial soils of Kern Delta have been rated in Classes 1 to 5. The different classes are badly mixed and are difficult to segregate. Much of the area regularly irrigated has a generally high ground water level which has resulted in reduced production. Prior to irrigation, the upper delta lands would have rated Class 1 and it is thought that with drainage much of this area can be restored to this class. Up to the present time drainage has not been undertaken. For its present condition the areas of Class 1 land are limited and the larger part of the present canal-served lands rate as Class 2.

The former bed of Kern Lake was rated as Class 1. Although the ground water level is high, alkali accumulation has not occurred at the surface. There is an area of very heavily alkaline land extending around the south of Kern Lake and between the canal-served areas south of Bakersfield, which is rated as Class 5. The lower portions of the delta near Buena Vista Lake also contain much alkali and have been rated as Class 3 or 5.

Buena Vista Lake rates as Class 1 for the lower portions, as far as soil is concerned, but is subject to submergence in years of large stream flow. In general, the upper soils high enough to have had natural drainage and the depressions subject to regular and deeper submergence are good land, except as some areas may have been injured by overirrigation. Intermediate areas of naturally high ground water level or marginal to the areas of regular submergence are heavily alkaline.

The higher slopes around the south end of the valley are generally Class 1. This includes the developed areas near Arvin and the south end around to the oil fields near Taft. The Class 1 rating applies out to the edge of the valley lands where steepness or roughness results in lower grades. There are minor areas of cultivable land on some of the local side streams which were not covered in this work as they are above the San Joaquin Valley area.

Hydrographic Division 2 — This division covers the southern portion of Tulare and Kings counties. The eastern portion of the division rates mainly as Class 1. It includes the upper portion of the Tule River Delta and the higher valley lands to the south. The upper delta lands are recent alluvial soils. The remainder of the higher lands are old valley filling soils. These are of the red hardpan types in the northern portion. The areas toward the south consist of soils relatively free from hardpan. At the north, the valley lands extend east to the contact with rough and stony land as classified by the U. S. Soil Survey. This represents the outcrop of the granitic formations of the higher areas. Toward the south end of this division, there is an intermediate area of tertiary formation between the valley and the higher foothills which consists mainly of residual soils. The upper limit of irrigable land is less definite here. The field work was extended as far as justified by practical considerations. The valley lands were generally rated as Class 1. This rating is fully applicable in the developed areas where any costs for leveling or breaking hardpan have already been incurred. Some undeveloped rougher areas were given a lower rating. Much of these higher lands are adapted to citrus culture and justify a more liberal rating on cost factors because of this, although little difference due to crop adaptibility was made in this work.

The smaller streams in the southern part of this division have not had sufficient flow to form deltas of any extent. The valley filling soils are less disturbed in this area. The outer areas in which the local run-off has spread contain Class 2 and 3 land, due to alkali in areas where such waters have collected.

The western portion of southern Tulare County approaches the general trough of the valley. The Class 1 lands of the upper deltas give way to the poorer lands of the outer deltas. These outer areas were not subject to sufficiently continuous or deep submergence to form the better type of lake bed land. Some areas have practically no agricultural value and were rated as Class 5, particularly in the southwestern part of the county. Marginal areas of Class 3 and Class 2 were rated as shown on Plate V. These lands of lower rating are all alkaline.

The southwestern portion of the division is within the area affected by Tulare Lake. The prevailing winds across Tulare Lake are from the northwest. There is a wide beach area at the southeast of the lake. The higher portions are not generally alkaline, although some alkali areas occur. Some of these lands do not show well sustained crop yields and were rated Class 2 because of such general conditions, rather than roughness or alkali. There is only limited irrigation in this area at present, except that of the Alpaugh Irrigation District. The better lands in this district were rated as Class 1, although they are not equal to the better Class 1 lands as this grade was used in this work.

The southern part of Tulare Lake is included in this division. The lower lands in the lake rate as Class 1, subject to their liability to overflow in years of large run-off. There is a marginal area of poorer land at the southwest side of the lake before the Class 1 lands of the west side plains are reached. The Class 1 area east of Kettleman Hills is relatively narrow. West of the outlying hills are some additional Class 1 valley lands. The hills are rated mainly as Class 5 because of roughness, but a few areas of better land occur.

Hydrographic Division 3—This division covers the Kaweah River Delta and adjacent higher valley lands to the east. The valley extends eastward to the contact with the granitic outcrop. Higher lands, except along the stream courses, are classified as rough and stony areas on the U. S. Soil Maps. These would rate as Class 5 due to roughness and shallow soil.

The higher valley lands, except where Kaweah River has eroded them, are generally old valley filling soils containing the red hardpan. These have generally been rated as Class 1, except for some rougher portions. There is much high class development on these lands.

The upper portions of the Kaweah Delta generally rate as Class 1. Some areas, where high ground water has resulted in alkali accumulation, are rated as Class 2. Parts of the delta consist of spotted soil where detail segregation is difficult. The rating shown includes some spots of Class 2 land in the Class 1 areas, in addition to those large enough to be shown separately.

Around the outer edges of the Kaweah River Delta, the lands are more largely of the lower grades. The outer areas subject to overflow and evaporation are largely alkaline. This generally grades from the Class 1 areas through Classes 2 and 3 to some very heavily alkaline Class 5 land. Only limited areas in this division were rated below Class 3. These areas of poorer land are found between the deltas of Kaweah and Kings rivers and between Kaweah and Tule rivers, as well as around the outer edge of the Kaweah Delta where they extend toward Tulare Lake.

Hydrographic Division 4—This division covers the general Kings River area, from the San Joaquin River on the north to the Kaweah River area on the south, and in the south includes the larger part of the Tulare Lake Basin.

The field work was extended to the outcrop of the granite on the east, which is shown as rough and stony land on the U. S. Soil Map. This represents the eastern limit of valley land. There are only narrow margins of Class 2 and 3 lands along the eastern boundary, as Class 1 areas extend nearly to the valley's edge. Some Class 2 channel cut land is shown along Kings River in Centerville Bottoms. With these exceptions, nearly all the east side area is Class 1 until the lower alkali lands toward the west are reached. Scattered through this area are small depressions, or pot holes, which formerly contained water, but which now are generally dry. Some of these areas are rated as Class 2 or 3.

Westerly from the canal-served areas of the Fresno and Consolidated Irrigation Districts, and extending to the formerly overflowed lands along Fresno Slough, is a large area of generally poor land. Due to high ground water levels, this area is alkaline. The degree of alkali varies, in general increasing toward the lower ground at the northwest. Some alkali extends into the western portions of the Fresno and Consolidated districts. These lands are rated as Class 2, 3 or 5, depending on the extent of the alkali.

Along the various overflow channels of Kings River toward the north, the trough or slough lands are less alkaline and of better quality. The better areas of these lands have been rated as Class 1, although the heavier soil texture and general conditions make such lands less easily handled than the better Class 1 lands of higher elevation. Some areas having alkali or where the cultivable areas are reduced or rough, due to channel cutting, have been rated as Class 2.

South of Kings River, the upper lands are similar to those on the north. These are mainly red hardpan lands now largely developed in the Alta Irrigation District and rated generally as Class 1. These extend eastward to the outcrop of the rough and stony land. There are areas of Class 1 recent alluvial soils near Kings River, northwestward from Hanford. There is a large area of poorer land around the southern side of the Kings River Delta, extending into the area between the deltas of Kings and Kaweah rivers. This is alkaline and rates as Classes 2, 3 or 5, depending on the degree of alkalinity. Some parts of these areas are understood to have been productive in the past; others have always been alkaline. The marginal areas were rated as Class 2. Some of the Class 3 land is similar to Class 5 in its present condition, but was rated Class 3 in recognition of the possibility that methods of reclamation may eventually be developed to restore areas that formerly were productive.

The bed of Tulare Lake is now largely reclaimed and cultivated. Due to the menace of flooding, crops are mainly grain. The lower lake lands and those near the stream inflow are generally of good quality. These have been rated Class 1 for the soil although their value for irrigation also requires consideration of the conditions relating to overflow. Class 1 also was used for the general area near Corcoran, except for some lands of generally poorer quality justifying a Class 2 rating.

Hydrographic Division 5—This division covers the lower west side plains, from Mendota south to Kettleman Hills. The surface is very smooth, with an even slope, so that little leveling is required. Along the east side, the lower areas include the Class 5 self-rising alkali land, so called locally due to the pulverizing of the surface soil when dry. Above the Class 5 land are narrow strips of Class 2 and 3 before the main area of Class 1 is reached.

Hydrographic Division 5B—This division covers the higher portions of the west side plains, from Mendota south to Kettleman Hills. It is not materially different from the adjacent lower portions of the plains in Division No. 5, except for elevation. The main valley area consists of very even and smooth Class 1 lands. The higher portions are of lighter soil texture, which will affect their water requirements. Surface ground water is alkaline and recovery of seepage and percolation losses would be of doubtful practicability in this area. The plains are recent alluvial soil of the Panoche series. The irrigable areas extend slightly into the higher residual soils. These rate Class 2 or lower, due to roughness, steepness and shallowness. The classification was extended into the higher cove valleys around Coalinga as shown on the land classification map.

Hydrographic Division 6—This division covers the lands on the east side of the valley, between San Joaquin and Chowchilla rivers, in Madera County. The area covered in this field work coincides closely on the east side with the boundary of the Division 6. The higher foothill lands are in Division 6A.

The higher valley lands are old valley filling soils, except where cut by local streams. These lands are rolling in surface and contain red hardpan, much of which is thick and occurs at shallow depths. A large part of the less favorable land was rated as Class 3. These are generally the higher lands on which the hardpan is thicker and more difficult to handle than in other areas of similar soil. Areas of less rolling surface, or with deeper or thinner hardpan, were rated as Class 2.

An area of Class 1 land extends across the county between the poorer hardpan lands to the east, and the lower alkaline lands to the west. This area includes some hardpan soils on which existing developments indicate that good crop results have been obtained. At the northwest, near Chowchilla, the lands are mixed Classes 1 and 2, so spotted in character that detail classification was impractical. About two-thirds of this area would rate as Class 1. The division between these lands and the Class 4 areas follows the revised boundary of the Madera Irrigation District, which was based on a similar land classification.

To the west of the Class 1 lands, the alkali increases rapidly. Except for a narrow zone of Class 2 or 3 land, the main area west to the lands near the San Joaquin River was rated as Class 4. This area is now largely flooded for pasture and represents typical land to which the description of Class 4 applies. If not rated as Class 4 for pasture, it would rate as Class 5 for crops.

Near the San Joaquin River, more regular overflow has resulted in better lands. Some of these were rated as Class 1, other areas of generally good soil, but channel cut, were rated as Class 2.

Hydrographic Division 7—This division covers the west side lands from Mendota to Tracy. The south end is a continuation of the Class 1 west side plains of Divisions 5 and 5B. There are narrow strips of Class 2 land along the San Joaquin River.

The west side trough lands extend from near Dos Palos northward to the vicinity of Newman. These lands are of heavy soil containing alkali and rate as Class 4 in the main area. They are known locally as grass lands and are used and useful only for pasture under swamping. Adjacent marginal areas were rated in Classes 2 or 3 where some crop use is or may be developed. The trough lands are located between the higher lands to the west, and the better lands, also higher, near the

San Joaquin River. Along the San Joaquin River are considerable areas of Class 1 land, with other areas rated as Class 2, due to being cut by old channels, although much of the included smoother small areas are Class 1 soil. West of the trough lands the Class 1 higher lands are narrower than the similar areas further south. The field work was carried to the rougher Class 2 and 3 areas toward the west.

From Newman north to Tracy, the west side area is nearly all Class 1. The lands slope up from near the San Joaquin River with no intervening area of low alkali trough lands. Along the river are some areas of Class 2 land, due to channel erosion or alkali. Near the hills the field work was carried through the Class 2 and into the Class 3 rough lands. The Class 1 lands are evenly sloping and require very little leveling for irrigation.

Hydrographic Division 8—This division covers the valley lands on the east side between the Merced and Chowchilla rivers. The field work, on which this report is based, was extended easterly to the Class 5 rolling lands of shallow depth. These upper lands later were reclassified in accordance with the standards used in the foothill areas. The classification herein discussed does not apply to the classification shown on the map for the part of Division 8 lying generally above Amsterdam and Yosemite Lake, and a narrow area along the east edge to the south. The soils in Division No. 8 are more variable than those in the areas to the north or south.

In the eastern part of the area covered, the lands are mainly rolling shallow hardpan soils. The field work was carried through the Class 2 and 3 lands to the higher Class 5 areas, as these classes were defined in this work. Development has proceeded much more slowly on the Class 2 hardpan lands, when water has been made available, than on the adjacent Class 1 areas. Below the Class 2 and 3 land is an area of Class 1 land extending across the division from north to south. Below this is a wide area of alkali land at the south and rough sandy land at the north. The better portions of these areas were rated Class 2. These are now largely in crop with poorer average results than on the Class 1 areas. The Class 3 lands are those rated as of very doubtful usefulness under irrigation. Below these lands are extensive areas useful only for grass land use, which have been rated as Class 4. Near the San Joaquin River are some better areas rated as Class 2. Near Stevinson the land is badly mixed in quality and the rating shown on the map is as definite as it is practicable to make it.

Hydrographic Division 9—This division extends along the east side of the valley from Merced River, north of the Tuolumne River, to include the areas of the Modesto and Waterford Irrigation districts. The field work herein discussed was extended east to the Class 5 rough lands. These later were reclassified with the areas in the foothills by the standards used there. The discussion herein applies only to the part of Division 9 extending eastward to around Dallas Lake, along the Tuolumne River, near Montpelier, and up Dry Creek and Merced River.

The higher east side areas are more mixed in quality than those in other parts of the valley and have been shown in more detail on the map. These higher lands consist partly of old valley filling soils of hardpan type and partly of residual soils. There are some bottom lands along local streams that are fairly smooth. Some of the heavier soils near Paulsell are used for rice. There are some areas too rough or too shallow to be rated higher than Class 5. While some scattered areas of Class 1 occur, the larger part of the better lands were rated as Class 2, with many areas, too poor for consideration in any present project, placed in Class 3. The Class 2 rolling hardpan lands have come into irrigation much more slowly than the adjacent Class 1 areas when canal service has been made available.

There is a wide area of Class 1 land extending across this division, from north to south, between the higher hardpan lands on the east and the poorer areas along the San Joaquin River. This consists largely of Fresno series of soils. It includes the larger part of the areas in the Modesto and Turlock Irrigation districts. Soils of light texture predominate particularly at the south end of the area near Delhi. The rougher portions of the sandy land were rated in Class 2.

Toward the San Joaquin River the soils become alkaline and were rated as Class 2 or 3, depending on the amount of alkali. Along the river some otherwise good lands were rated as Class 2, due to the proportion of the gross area which is channel cut.

Hydrographic Division 11—This division covers lands on the east side of the valley, from Mormon Slough south to the Stanislaus River, together with the lands south of the Stanislaus River in the Oakdale Irrigation District. As in other adjacent divisions further south, the basis of classification used in the valley lands was applied until Class 5 land, by these standards, was reached. The higher lands have been classified by the standards used in the foothill areas to the east. The eastern portion of Division 11, as shown on the map, is not included in the following discussion.

The upper lands covered by this work are shallow hardpan and residual soils rated as Classes 2 or 3. The Class 3 lands were so rated, on hardpan or shallowness and on roughness. The Class 2 areas are usually somewhat rolling as well as having hardpan. Under the irrigation systems in this area, even the Class 2 hardpan lands have come into use very slowly.

Near the San Joaquin River are areas of Class 2, due, in some parts, to alkali and in others to roughness caused by channel cutting. Some Class 2 alkali land extends into the general area of Class 1.

Summary.

The results of the classification of the valley floor lands covered by the survey described in this report and in accordance with the standards set forth herein are summarized by hydrographic divisions in the following table compiled in the office of the State Division of Water Resources.

Class 1 lands are those which are able to meet the maximum costs of irrigation and represent 52 per cent in the upper San Joaquin Valley and 41 per cent in the Lower San Joaquin Valley of the total gross area covered by the survey in each respective portion of the valley. Class 2 lands have some defect in quality, which reduces their ability to meet the costs for water. The average in this class represents, of the total in each respective portion of the valley, 19 per cent in the upper and 28 per cent in the lower San Joaquin Valley. Classes 3, 4 and 5 are lands of too poor quality to justify permanent use of water, even of local supplies, under present economic standards. In aggregate, they include 29 per cent of the gross area in the upper and 31 per cent in lower San Joaquin Valley portions covered by the survey and report.

CLASSIFICATION OF VALLEY FLOOR LANDS IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS

For land classification areas, see Plate V.
For boundaries of Hydrographic Divisions, see Plate VI.
Figures in table are for areas covered in survey only.

Hydrographic Division	Gross area in acres					
	Class 1	Class 2	Class 3	Class 4	Class 5	Total
Upper San Joaquin Valley—						
1	706,141	316,259	310,923	5,565	240,077	1,578,965
2	469,971	231,305	111,842		138,051	951,169
3	233,749	101,976	45,961		14,525	396,211
4	793,482	237,200	167,487	8,963	164,237	1,371,369
5	304,316	21,034	22,950		53,576	401,876
5B	239,182	37,608	8,628		25,592	311,010
6	140,061	106,160	104,897	156,135	11,371	518,624
Lower San Joaquin Valley—						
7	305,700	124,149	63,342	128,901	1,173	623,265
8	114,416	154,078	83,753	85,201	3,382	440,830
9	184,062	134,732	95,686		16,922	431,402
11	160,560	106,630	76,845		7,395	351,430

APPENDIX B

GEOLOGY AND UNDERGROUND WATER STORAGE CAPACITY OF SAN JOAQUIN VALLEY

by

HYDE FORBES
Engineer-Geologist

July, 1930

34—80997

TABLE OF CONTENTS

GEOLOGY AND UNDERGROUND WATER STORAGE CAPACITY OF SAN JOAQUIN VALLEY

The object of this investigation and report is the determination of the locations and capacities of underground water storage reservoirs which may be utilized in the irrigation development of the San Joaquin Valley. The study divides itself logically into two parts; first, that of the general geology of the region through which the underground storage areas can be broadly delineated and, second, the detailed consideration of local areas to establish the location of underground storage reservoirs, to estimate their capacity and to determine the practicability of their utilization for the storage and extraction of water supplies in irrigation development.

GENERAL GEOLOGY

The geologic history of the San Joaquin Valley is determined in part through the study of the geologic structure and formations of the mountain ranges bordering the valley plain, in part through the study of the present surface topography, in part through the study of the characteristics of the material penetrated in well drilling, but in a large part through the study of the chemical character and temperature of waters brought up from varying depths and horizons through water wells, and the well water levels under varying conditions of pumping or nonpumping and seasonal or cyclic changes.

Taking up first the geologic history of the San Joaquin Valley, as revealed by geologic evidences read from the formations and their structure, as exposed over the Coast Range, and the geologic development of the Sierra Nevada briefly, it is found that during late Cretaceous time the Franciscan rocks protruded above the sea from a point south of Livermore as an elongated island some 15 to 20 miles wide at the north and extending with lesser widths southeasterly to a point west of Tulare Lake. The Sierra Nevada area consisted of granitic intrusions in older crustal rocks whose height separated the Great Basin from the sea. Lying between the Sierra Nevada shore line and the islands was the San Joaquin geosynclinal trough. At the close of Cretaceous time occurred the Coast Range uplift which entirely enclosed the central geosynclinal trough except at the southern end.

The accumulation of a great thickness of sediments, derived through erosion from the Sierra Nevada and Coast Range areas, continued uninterrupted in this geosynclinal trough under varying crustal conditions until late Tertiary time. These crustal conditions consisted largely of the depression of the continental areas after deposition built up the floor of the geosynclinal trough near the land bodies. The body of water occupying the trough varied in depth and in character from a deep channel to a land locked gulf during all this time, never losing, however, its marine character and the sediments laid down were marine deposits.

From the late Tertiary through Pleistocene time occurred the mountain-making uplift, which was an earth movement of great magnitude and which raised the Sierra Nevada to their present height. It was accompanied by volcanic activity and outflow of lava over wide areas, the rejuvenation of the Sierra drainage with its development of the present Sierra topography, and the uplift of the deformation of the sediments laid down on the floor of the sea, resulting in the land mass of the Coast Ranges and Coast Valleys and the development of the Tehachapi Mountains enclosing the valley on the south.

Geologic Structure.

In a broad way, the structure of the Diablo or Coast Range is anticlinal and its eastern flank is composed of a great monocline of sedimentary strata dipping toward the San Joaquin Valley. This monocline is broken in regularity, through being subjected to compressional forces, by a series of anticlinal and synclinal folds, the most easterly of those now exposed being the Kettleman Hills-Coalinga anticline and which is continued in the Lost Hills structure.

The Tertiary uplift of the Sierra raised the western flank, without distortion or displacement, above sea level and the marine sediments lie exposed against the Sierra north of the San Joaquin River as a series of unaltered beds of clay, shale, loosely cemented sandstones and gravelly formations. The Fresno, Chowchilla, Merced, Tuolumne, Stanislaus, Calaveras and Mokelumne rivers are all intrenched in these formations at their upper valley portions. This area, that embracing the Coast Range uplands and the San Joaquin Valley trough intervening, laid beneath the sea during the major portion of geologic time from the Jurassic to the end of the Miocene. Consequently, the marine sediments found exposed and eroded over the uplands should lie, with possibly some variation as to thickness, in the same geologic sequence under the entire San Joaquin Valley region. Through uplift they have been brought relatively close to sea level over portions of the valley trough. The compressive forces accompanying the uplift found relief through possibly additional folding and faulting in the valley trough area parallel to the Coast Range structural trend. All of this structure and marine sedimentary bedding now is buried under a thickness of alluvium and the buried geologic features are largely controlling in the ground water hydrology of the region. The buried features have not all been revealed, but with continued deep well exploration in search of petroleum the knowledge of subsurface conditions is being continually augmented. In the present state of knowledge certain structure features have been established, possibly with some indefiniteness, but sufficiently to be used as a guide in the present study. These may be enumerated as follows:

(1) A profound fault displacement with the downthrow on the west extending from one of the northwest-southeast faults of the Tehachapi Mountains, possibly the Poso Creek fault, northerly along a line which passes in the vicinity of Corcoran, Mendota and Tracy.

(2) The block displacement along this line has caused both blocks to rise toward the north, the depth to marine sediments of a given age, which has no indication on the surface, becoming increasingly greater southerly.

(3) General uplift of the Sierra Nevada, raising their western flank to elevations above sea level.

(4) Possibly some additional folding due to compression of the beds west of the fault, raising portions of the buried marine sediments closer to the present ground surface.

(5) A long period of stability during late Tertiary and Pleistocene time during which detrital material was carried down to the valley, building up a great valley plain to heights well above sea level, followed by a subsidence (still in progress) in the valley area along the valley fault, causing the Sierra streams to achieve new base levels and favoring the erosion of their older alluvial cones nearer the mountains and deposition of modern alluvium at lower elevations, which all presented:

(6) A rugged or uneven topography now partially buried by the more or less uniform geologically modern sediments of the San Joaquin Valley plain.

Valley Sediments.

The sediments that lie beneath the floor of the San Joaquin Valley vary somewhat in their physical characteristics and density through the upper thousand feet, and the mineral content of the waters contained therein vary with the conditions under which they were laid down and the physical character of the sediments. The material brought from the Sierra was carried into bodies of water. The heaviest boulders and gravel were dropped close to the Sierra shores, building up a subaqueous delta, which, as it grew in proportion, finally extended as a land body into the water body. Great thicknesses of finer sediments, however, were first distributed over the bottom of the inland branch of the sea and later over the bottom of the large fresh water lakes which occupied the San Joaquin Valley trough. Off-shore currents sorted and distributed these sediments into thicknesses of sands and clays. Upon consolidation, which varied with the age, the beds changed to loosely cemented sandstone and shale and entrapped the waters, salt or fresh, in which they had been deposited.

The San Joaquin River and its northerly lying tributaries have been sufficiently constant in carrying large quantities of water to maintain an open drainage channel through the San Joaquin Valley to Suisun Bay. The extensive deltas of the Kings, Kaweah and Tule rivers have continuously built land bodies outward into water bodies from the Sierra foothills and recent alluvial deposits have covered over the older formations exposed to the north and south. At Lindsay, wells of a few hundred feet in depth penetrate to or into marine deposits and yield salty water. Between the Tule and Kern rivers there is no important drainage. Tertiary beds of soft sandstone, clay and gravel bordering the Sierra are there exposed. The Kern River is intrenched in its upper valley portion in these older formations, but has built up a great alluvial delta over the southern portion of the San Joaquin Valley.

During the period of sedimentation, while the marine conditions were being displaced by fresh water conditions, the sediments laid down were those embraced within what is now known as the Tulare formation. The base of the formation is marine in origin and yields fossil shells and salty water. It differs from the older formations, so far referred to, in that the origin is in part marine, in part fresh water and in part probably subaerial. It is marked, at its marginal positions along the valley, by the prevalence of prominent beds of boulder gravel, which is more coarse and abundant than in any of the Tertiary formations. It probably marks the transition from salt to fresh water conditions to the establishment of present land conditions. Distortion, tilting and displacement continued for a long period over the Coast Range region and the Tulare formation, in its later subaerial and fresh water phases as well as marine, is raised and exposed in the Kettleman Hills. This formation is slightly consolidated, but otherwise it does not vary in its physical characteristics from the alluvial material which makes up the present surface of the valley floor.

Surface Topography.

The more recent geologic history is revealed to some extent by the present surface topography of the valley. The history of the Sierra streams has changed with the occurrence of crustal movement and climatic changes. Prior to the late Tertiary uplift, Sierra slopes were gentle; sedimentation took place in part upon land surfaces and great bodies of sand and gravel were deposited by the streams along their channels. After the disturbance, the streams cut new channels, abandoning these old sand and gravel bodies, some of which had been buried by lava flows. These bodies are known as the Tertiary gravels, from which gold has been obtained through placer mining developments. The more southerly Sierra streams became rejuvenated and, with increased slope, their powers of erosion were greatly increased. All the Sierra streams, and Coast Range streams as well, have carried far greater quantities of water and enormously greater loads of sediment than they now carry.

The climate over the region during early Quaternary time was cold and humid. Great ice sheets protruded far into the United States and glaciers of the Alpine type covered the high Sierra. The melting of the glaciers, as the climate tended to the semi-arid, established the Sierra drainage and great quantities of sediment were carried into and through the San Joaquin Valley trough from the Sierra. In the past, as now, rainfall decreased southerly. The streams south of the San Joaquin River were less constant in flow, subject to wide variation seasonally and within the season as to quantity of water carried. Glaciers were not as heavy nor did they descend to as low an elevation as further north. Hence through drainage, as existed for the northerly streams, was not established by the Kings River and those to the south. Furthermore, few northerly Sierra streams were opposed by any important drainage from the west, while great stream deltas, such as those of Kings River and Los Gatos Creek, were built up in the south to oppose each other through deposition of sediments until they protruded above the surface of the sea and divided the valley into great basins. The fresh water of the streams was discharged into these basins, displacing the salt water until there were formed large fresh water lakes.

The San Joaquin River flows in a southwesterly direction to Mendota, thence turns northwesterly, probably controlled by the geologic structure, to collect the water of its tributaries. From the San Joaquin River north the surface topography reveals the past history. While fluctuating lakes existed in this region, they were better drained and were not the continuous and extensive features as were those to the south. South of the San Joaquin River, the Kings, Kaweah and Tule rivers and minor creeks, and the Kern River have built up great alluvial fans or deltas at the base of the Sierra Nevada on the east, while Los Gatos Creek has done the same thing from the west. The fans or deltas extend into the Tulare Lake Basin and retain the water from these streams, at least temporarily, in the area. The sediments have been largely retained, resulting in the alluviation of an extensive structural depression. Sedimentation has continued to build up delta barriers and raise the bottom of the fresh water lakes until the whole valley floor has been brought up to its present level and condition.

The climate, tending toward the arid, has been characterized by wet and dry cycles such as are being experienced at present. The northerly lakes, being better drained, were intermittent in character, depending upon wet cycles for their lake characteristics and in dry cycles being reduced to swamps. Wind blown sand, carried over these swamps, formed the sand beds that, with the next wet cycle, were covered by lake waters which deposited a clay bed over them. The intermittency of flow and the building up of delta barriers have favored the occurrence of more constant large bodies of fresh water south of the San Joaquin River. The surface of these lakes has fluctuated in elevation and extent with the occurrence and recurrence of wet and dry cycles, but they have been present to some extent during the process of the upbuilding of the valley right up to the present time. During dry cycles the stream deposits have been laid down over dry lake beds, and wind-blown sands have covered dry lake or swamp areas and built up a broad level plain area through which many drainage sloughs passed. Between this plain and the Sierra foothill belt, in which the streams have entrenched themselves, are limited areas of stream built alluvial fans or deltas. West of the plain, north of Mendota, there has been built up a piedmont slope to the Coast Range which is fairly uniform and lacking in extensive alluvial fan or cone development.

Throughout a long period of Quaternary time this process was proceeding until a great valley plain was built up to well above sea level and occupying the present area of the Sacramento and San Joaquin valleys. Modern geologic time has been marked by a continued, gradual subsidence of the central valley area and San Francisco Bay area, being greater in amount (over 300 feet) at the Golden Gate and decreasing north and south along the coast and along the valley fault. This subsidence has allowed the intrusion of sea water into the San Francisco Bay and the San Joaquin Delta regions. It caused the Sierra streams to achieve new base levels and favored the erosion of their older alluvial cones at their apexes, leaving those surfaces as boulder capped hills in the foothills and compact (Madera and San Joaquin type) soil areas on the upper plains bordering the entrenched modern stream channels, with the lower plains being composed of a cover of open recent alluvial deposits (Hanford soil type) marking the geologically modern alluvial fans of the Sierra streams.

Well Penetration Records.

The fresh water lake condition of the trough of the San Joaquin Valley has disappeared to some extent through climatic changes, but largely because man has diverted the waters which formerly passed directly down stream channels to replenish the lakes, and has spread them widely over the valley to be dissipated through evaporation and plant transpiration and absorbed by the porous sediments. The connecting swamps have been drained through the excavation of channels.

Past conditions are readily discernible from the present surface topography, and in addition lake bed, or, as they are termed, lacustrine materials, are uniformly brought up from relatively shallow wells over the central portion of the valley.

It is usual for the logs of wells in the trough area to show alternate bedding of sands and clays that, with depth, are consolidated into shaley or cemented, packed, or hard beds which can be readily identified as indicating lacustrine conditions. The clay beds, being lacustrine in origin, while not constituting a wide spread unbroken blanket at one level, are extensive and continuous in contrast to the higher lying and overlying lenticular bodies of clay found in stream-formed alluvial deposits. Furthermore, being laid down as finely divided mud underneath water, they contain no living vegetable matter and are quite impervious in contrast to alluvial clays, which contain numerous openings due to shrinkage upon drying and the rotting out of rootlets and other vegetable growths.

For that reason, throughout the east central portion of the San Joaquin Valley from Buena Vista Lake north, wells which penetrate to depths in excess of 100 to 150 feet enter into a horizon in which the materials were laid down, at least to 600 feet in depth, under more uniform conditions of lake bed distribution alternating with alluvial deposition. The materials making up this horizon, although permeable and saturated, resist the upward or downward movement of water so strenuously that for all practical purposes its shingle-like structure separates it from the overlying alluvium. The water originally contained in this horizon was so confined by the resistance of the materials to direct upward movement that it developed a head which a well, on removing the resistant material, allows to be registered as artesian flow or water level. Similarly, when water is pumped from the horizon and the pressure reduced, provided the well casings are not perforated at higher levels, the same resistance that developed the head prevents the surface ground water from lowering to the horizon drawn upon.

The full thickness of the marine sediments is not known, but wells drilled in the valley have penetrated to them and into them, bringing up fossil evidence and producing water whose chief mineral constituents are marine salts. Due to the fault displacement, the marine sediments are reached at greater depth over the southwesterly portion of the valley and in the Tulare Lake region than on the east side and in the north end of the valley, yet the deeper water wells on the west side and in the Tulare Lake region penetrate into beds of Tertiary age and yield salty water and carbonic and hydrocarbon gasses.

Three wells drilled by the Associated Oil Company east of the fault on Sections 26 and 14 of Township 15 South, Range 18 East, and Section 35, Township 13 South, Range 16 East, which lie south and west of Fresno, to depths around 6000 feet showed that fine grained shales, sandy shale and coarse sand, without organisms, were to be found from the surface to about 4000 feet. This represents the Recent alluvium, Tulare and Etchegoin Pliocene formations, with probably the Recent and Tulare occupying the first 3000 feet. As the Tulare formation varies in thickness from 2000 to 3000 feet along exposed sections near Coalinga and cores were not taken above 1800 feet in the wells drilled, it is impossible to determine the thickness of Recent alluvium overlying the Tulare from these or other oil drilling records. In fact, well logs are of little aid in this relation, as there is but little physical distinction between the two formations.

GROUND WATER RESERVOIRS OF THE SAN JOAQUIN VALLEY

It is apparent, from the geologic history of the region, that the San Joaquin Valley, as outlined by its present-day surface, is not a unit mass of unconsolidated sediments which will readily absorb water passing over the surface and transmit it uniformly throughout and to great depth. Rather, it is made up of a great many aquifers of varying types, which may consist of formations in whole or in part water-bearing. These aquifers all have distinctive properties in relation to the absorption, retention and transmission of water. They may be separated from each other laterally or horizontally, or both, by non-water bearing or relatively impermeable formations or parts of formations; and there exist areas, horizons and zones in which the ground water contained has widely variant physical and chemical properties. For example, the water derived by pumping from the sand beds within the Tulare horizon or more recent lacustrine deposits is free to circulate within them and has been and may be fed into them laterally from the coarse material of the upper or higher portions of stream deltas over wide areas which have free horizontal connection with those sand beds. Vertical replacement or replenishment, however, can only take place in the sand beds beyond the limit of their confining clay beds. This phenomenon has been proved through the physical effect of pumping for drainage from the Turlock Irrigation District south.

Areas of the Valley Not Adapted to Ground Water Storage.

The areas of the San Joaquin Valley adapted to ground water storage are those which will readily absorb the water passed over their surface to replenish water drawn from storage for irrigation use. Such areas can be defined broadly through the elimination of areas not so adapted.

That area lying west of the valley fault, the eastern boundary of which is a line extending southeastward from Newman to Corcoran, with a width of five miles at Newman and 20 miles or more at Corcoran, is not adapted to the desired use. The waters from shallow wells in the recent delta deposits of the Sierra streams are uniformly soft, while waters from shallow wells on Los Gatos Creek fan and those to the north, which are fed by streams from the Coast Range, are high in sulphates and low in HCO_3 and Cl. The Tulare formation and marine sediments are reached at relatively shallow depths over the area and the deep wells—over 400 to 500 feet deep—contain no sulphates, but are high in HCO_3, with the alkali bases exceeding the calcium and magnesium content. The deepest wells—from 800 feet up—are bringing up marine water high in chlorine and containing other toxic salts (Boron). The soils of this area are inclined to be hard and contain somewhat impervious or hardpan layers in which the salts, including possibly those that are toxic in effect, have accumulated.

Surface water spread in irrigation over this area must be kept in downward circulation and the area thoroughly drained by pumping and wasting the recovered water into the San Joaquin River, where it can be mixed with large quantities of fresh water. Unless such provision is made to keep the salt content down and remove it from the soil there will occur pronounced crop injury. It might be stated that with the use of well water in this area to date, with few exceptions, the salt concentration in the top soil has become sufficient to injure certain crops.

The Tulare Lake bed area and its continuation southerly to the Buena Vista Lake bed area is not adapted to ground water replenishment. The encroachment of the deltas of the Kings, Kaweah, Tule and Kern rivers over the lacustrine deposits has superimposed recent alluvial sediments of shallow thickness, but as a general rule thickness sufficient to be adapted to ground water charge and recovery lies northeast of a line passing through Corcoran, Alpaugh, Semitropic, along Goose Lake Slough to Connor, thence eastward.

Types of Ground Water Reservoirs.

It might be well to consider the type and character of the recent alluvial deposits now occupying the uppermost thickness of the San Joaquin Valley in relation to their ability to absorb, contain and deliver water.

First, the series of topographic depressions which were filled with water, either marine or through stream flow from the surrounding land. Material in suspension carried into the depressions was deposited and the material in solution concentrated by evaporation so as to be precipitated. In this way the depressions in time were completely filled. Such deposits contain materials of such a cemented and compact nature as to be rendered relatively impervious. Where a stream entered the bodies of water the current was checked, but not immediately stopped, at its mouth. If the stream carried abundant sediments, much of the heavier material would be dropped at the first checking of velocity and deposition would continue from the stream current as it became more and more checked and diffused through the body of standing water. At the same time the building up of the delta land tended to check the current in the upper channel and thus alluvial deposits, continuous with the delta, were extended landward.

In the course of the upbuilding of such deltas in an inland branch of the sea or lake, crustal movements that halt in deposition or changes in climatic conditions have been such that the stream and wind depositions of sand are overlaid by still water deposition of coloidal material, forming a "clay blanket." This clay is composed of extremely finely divided rock flour and flakes, contains no vegetable matter in a living form, is high in mineral salt content, is extremely plastic so no cracks or joints can form and is practically impervious. Thus, there have been deposited a series of porous and permeable sediments lying in horizons and zones between relatively impermeable materials.

The east central portion of the valley is underlaid by such a series of alternating sand and clay beds, of both the Tulare and later periods. In places the sand beds are a relatively small percentage of the vertical section. Further to the east the sand beds become coarser, and in places gravelly, and form a greater percentage of the vertical section. The confined sand beds were originally completely charged, and the water contained therein was under artesian pressure. Draft from wells penetrating the artesian horizons has lowered the water level to far below ground surface. The raising of the ground water level over areas which undoubtedly are the sources of water and hydrostatic head of these artesian waters has not had the effect of restoring the artesian conditions.

The Sierra foothill belt surface is made up of a series of soils which might be termed residual, as distinct from the stream deposited alluvial soils in that their origin is through the weathering and modification of older Tertiary sediments and rocks of many varieties. The top soil is modified by vegetation and cultivation, but the subsoil is heavy textured and compact, containing harpan layers and seams of calcareous material. At lower elevations these soils represent the surface of earlier (Pleistocene) stream deltas below which the modern streams have cut. The soils are the compact Madera and San Joaquin type, having a red color which distinguishes them from the modern alluvium, but in drilling samples the differentiation is difficult if at all possible, because both produce sands consisting of quartz grains with undecomposed fragments of feldspars and flakes of mica. With increasing age the decomposition or oxidation of the ferromagnesium mineral flakes contained in the older alluvium near its surface provided the iron oxide which gives it the characteristic color and acts with calcium carbonate as a cementing material which has caused the formation of an ''iron'' hardpan in the upper thicknesses. Beyond the reach of oxidizing agencies the color is not marked, except where ground water circulation through certain gravel and sand channels or members has carried on the oxidizing and cementing processes, thus sealing otherwise good aquifers. As a whole, the formation is largely made up of the products of decomposition, kaolin (clay) from the feldspars which fill the interstices between the stable quartz fragments, and is not one which absorbs water readily, nor does it yield water freely to wells, in large quantities. The surface soils, with their hardpan content, will not freely absorb surface water or pass it underground. Consequently water is shed and drainage patterns develop as stream valleys or streamways eroded in the predeposited alluvial material, and sediment transported by these minor streams is deposited in their beds within the confines of close spaced banks or over adjoining areas as a thin veneer of open textured sands. With changes in amount of stream flow or grade of the channel, these deposits accumulate in the streamway with the subsequent stream flow passing over their surface. In this manner limited absorptive areas of shallow depth are formed but they are not of general economic importance in connection with the present study.

It is apparent, that the underground storage capacity, subject to the greatest charge and recharge from surface water sources, and best adapted to the desired uses, will be limited largely to the geologically modern alluvial deposits. Their extent is shown generally on Plate B-I and comprises the modern alluvial fans of the major Sierra Nevada streams of the San Joaquin Valley, the alluvial slopes or plains formed by the mergence of these fans with each other, flood plain terraces bordering these streams in their upper entrenched channels, and the present and recently abandoned streamways.

The modern alluvial fan deposit can be characterized as a heterogeneous mass of fragmental stable rock material which is the product of disintegration rather than decomposition, containing limited lenses of well assorted sand and gravel laid down as stream channels. These channels were abandoned by the stream and their depressions were grown over by vegetation and filled in with fine wind transported material. They were cut at intervals throughout their lengths by subsequent surface stream erosion in the establishment of new channels and are thus left as lenticular bodies of sand and gravel imbedded in a matrix of finer or poorly assorted material. Sections of such a formation or deposit, as exposed in railroad cuts or other excavations, show no continuity of materials of like texture or grain size, but rather a chaotic mass in which fairly well defined lenticular bodies of gravel will give way abruptly to bodies of finer material. In this way the deposited materials are merged by the ramifications and cutting of surface stream channels into one unassorted alluvial fill, in whose upbuilding wind action and vegetation also have played an important part. All the materials making up the deposits are porous and permeable, the degree of porosity and permeability varying widely throughout the deposited materials, but the whole capable of absorbing water at relatively high rates and yielding it freely to wells. In the San Joaquin Valley many fans have developed in proximity to each other, expanding laterally, and merging into one broad and extensive alluvial slope which terminates in a relatively flat alluvial plain.

Flood-plain terraces are the minor alluvial plain deposits, left in the form of terraces along the major tributaries as the stream's history advanced. These river terraces are remnants of former flood-plains, below which the streams which made them have cut their channels. These stream terraces are ideal areas for the spreading of surface water in recharging underground storage. They have a permeability and absorptive capacity exceeded only by the streamway itself. Few materials in their natural formation possess the degree of homogeneity, in reference to porosity and transmissibility, which characterizes the deposits making up the present or recently abandoned beds of streams. The interstital space in such a deposit usually ranges from 40 to 50 per cent of the mass and seldom is it less than 33 per cent. Thus, highly permeable deposits of better assorted detrital material underlie the surface streamway or river channel. It is more or less definitely limited at its bottom and sides by material of lower permeability, and is quickly recharged by the passage of surface water over it. In fact, surface water does not proceed until the streamways are filled. The capacity is somewhat limited, but it tends to recharge the less permeable material, which absorbs water at slower rates and through which the stream has cut its way.

Capacities of Ground Water Reservoirs.

The determination of the storage capacities of ground water reservoirs was aided materially by studies of records of water levels in wells scattered throughout the San Joaquin Valley, well logs and locations and capacities of pumping plants. The provisions for replacement of water were studied in sufficient detail to determine that ground water recharge was feasible from a physical standpoint. Stream and ditch channels were examined in the field as to carrying and absorptive capacities and possible spreading areas were located. Available stream and canal seepage measurements were collected and additional data on absorption in certain stream channels were obtained by field measurements. From a study of these data, which are voluminous, average seepage factors were deduced for canal and ditch systems on modern alluvial fans, for natural channels and depressions, for river bed sands and for spreading areas on sandy loam soils of alluvial deltas. These seepage factors are set forth in Table B-1. They show the average rates of absorption under various conditions. These rates may or may not be continuous. The values shown for excavated canal and ditch systems on modern alluvial fans are generally continuous throughout the irrigation season. The factors for natural channels and depressions may be reduced to those of adjacent material having lower permeability, after a certain period of operation. The factor shown for river bed sands would be reduced, in many instances, after becoming charged due to a lower rate of absorption of less permeable adjacent or underlying material. The factors given for spreading areas on sandy loam soils are based on the assumption that water would not be applied more often than one day in each fifteen.

TABLE B-1

SEEPAGE FACTORS FOR CHARGING GROUND WATER RESERVOIRS IN SAN JOAQUIN VALLEY

Conditions of charging	Seepage factor	
	Depth per day per unit of area covered, in feet	Per square foot of wetted perimeter, in second-feet
Excavated canal and ditch systems on modern alluvial fans	1.3	0.000015
Natural channels and depressions	3.4	0.000040
River bed sands		0.0004 to .0005
Spreading areas on sandy loam soils of alluvial deltas	2.0 to 3.0	

Irrigation activity in the San Joaquin Valley was largely dependent upon surface water during the twelve year wet period 1905–06 through 1916–17. Irrigation water was distributed by means of canals and ditches, the irrigated areas being for the most part limited to those convenient to surface water sources. Ground water levels rose under these areas to heights close to ground surface. Excess flows passed into Kern, Buena Vista and Tulare lakes and northerly into the San Joaquin River.

In the fall of 1905 the Tulare Lake bed was dry. The excess flows of 1905–06 carried about 1,000,000 acre-feet of water to the lake, raising its level to the 192-foot contour. Continued flow kept the lake bed covered to varying depths until 1918. The evaporation from the surface water body (based upon tests made at Tulare Experimental Station) was 4.4 feet in depth per annum. Ground water levels were brought to heights, allowing evaporation loss over wide areas and the accumulation of alkali salts in the top soil so that, for the period 1905–06 through 1916–17, there occurred large wastage of water.

Subsequent to 1917, high prices for agricultural products encouraged the development of lands without surface water supplies. The falling off of stream flow during the twelve year dry period, 1917–1929, and the mechanical development in wells and pumping equipment caused an increasing draft to be made upon ground water for an irrigation supply. The lowering of the water table was progressive, with the accumulative result that in the fall of 1929 the water table over the greater portion of the valley was lowered to depths below ground surface which prevented evaporation loss and aided in the reclamation of alkali lands.

The lowering of the water table level through pumping during periods, seasonal or cyclic, of deficient run-off provides a water supply and storage space in which to conserve excess or surplus water during periods of excess run-off. Such conservation is effective and desirable when the proper balance is maintained through a combination of pumping and replacement. Areas wholly irrigated from surface waters, brought to and spread over the area through unlined canals and ditches, have direct replenishment to ground water storage, but unless free natural drainage is present or pump drainage is practiced ground water levels are brought to detrimental heights. Areas depending solely, or to a large extent, upon pumped ground water supplies must have replacement provided through diversion and transportation of excess surface water from sources without the area, to be applied directly to the area, as in irrigation, or placed in channels for absorption. Soil and subsoil characteristics most favorable to the absorption and transmission of water underground are found to allow only slow movement of limited quantities of water so that only a small portion of the overlying land can be served from ground water sources without a progressive lowering of the water table beneath the area, unless such replacement provides an excess of absorption over draft during certain periods. With adequate replacement provisions and the maintenance of average water table levels, it appears physically possible that ground water storage can be created in sufficient amount to provide perfect irrigation service and probably complete conservation of the waters of the San Joaquin Valley.

The types of ground water reservoirs previously described comprise distinct physiographic units making up the modern alluvial floor of the San Joaquin Valley. Twelve days were spent in the field mapping the surface extent of these absorptive areas, using U. S. Geological Survey maps, scale two inches equals one mile, as a base. The subsurface characteristics of these units were revealed through a study of a large number of penetration records of wells widely scattered over the valley. A comparison of the characteristics so revealed with the yield of the wells and a comparison of the lowering of the water table from 1917 to 1929 with the irrigation demands of areas dependent wholly or partially upon ground water supplies, allowed estimates to be made of the average effective capacity of the soil volume drained per foot of water table lowering. These results were checked with indicated drainage factors obtained by analyses presented in Chapter IV in the body of this report for present developed areas, in which quantities of depletion and water table lowering could be determined. The effective voids of the materials were found to vary from 10 to 20 per cent so an average factor of 15 per cent was assumed for alluvial fans of the major streams, 12½ per cent for interareas in the southern end of the valley, and 10 per cent for the sand and clay areas in the northerly end of the valley trough.

Ground Water Storage Capacity South of San Joaquin River.

For the purpose of broad consideration, absorptive areas in modern alluvium on the eastern slope of the San Joaquin Valley subject to subdivision in the consideration of local ground water reservoir areas in relation to the rate and method of charging their capacity and utilization of that capacity, are outlined on Plate B-1. The areas south of San Joaquin River are located in divisions 1 to 4, inclusive. Division 5, on the western slope, has been previously eliminated from consideration as a ground water storage area. The ground water storage capacity of each of the larger units was determined by obtaining the surface area from the large scale topographic maps, obtaining from the same source the average ground surface elevation over each township or fraction thereof and reducing that elevation, where necessary, to compensate for reduction of effective storage levels due to natural drains; determining the average ground water elevation from the 1929 ground water contour maps for corresponding townships or fractions thereof and assuming that the available storage space is that lying between the 1929 water table level and a level ten feet below the average ground surface and applying the assumed drainage factor to the storage space. In areas surface irrigated during the past dry years, the 1929 water table level is relatively high and reduction of this level by pumping draft or reallocation of surface water is assumed, in certain areas, to make available ground water storage capacity.

**Hydrographic Division 1.* The modern alluvial fans of the Kern River and the Poso Creek fan in Kern County, south of the seventh standard parallel, occupy a surface area of 525,000 acres. Over a considerable portion of this area the water table is maintained at a high level through canal seepage and irrigation return. The drilling of wells and installation of pumping plants in the high ground water area, within the past few years, has proved so successful in the matter of yields, low cost and complete control of irrigation supply, that it is not beyond the range of probabilities that portions of the surface water supply may be allocated to ''rim'' lands not so fortunately situated as to ground water resources, and ground water storage be made available through draft upon and replacement of ground water over the reservoir area. An average lowering of the water table to 60 feet below ground surface would provide about 3,750,000 acre-feet of storage capacity which is probably in excess of that required for complete conservation through underground storage.

Hydrographic Division 2. The northerly three miles of Kern County and that portion of Tulare and Kings counties lying south of the area, now surface irrigated from the Kaweah and Kings rivers, consists of a modern alluvial veneer laid down by Deer Creek, White River and lesser streams over the more compact cemented older alluvium and Tertiary sediments and the modern alluvial fan of Tule River. The streams have entrenched themselves at higher elevations in the older sediments and the stream flood plain deposits fill the limited

* For boundaries of Hydrographic Divisions see Plate V, Chapter II.

trenches and form underflow conduits previously described. The well logs of the area show the modern alluvial fan of Tule River and the accumulation of sediments bordering the Tulare Lake bed to have attained sufficient thickness to constitute an important ground water reservoir. Taking into consideration all types of ground water containers, the surface area totals 322,000 acres.

The greatest water table lowering during the past twelve years occurred over those portions of the area where the water entrapped in the older sediments, which are not subject to ready replenishment, has been withdrawn. Such areas will have to be served surface water to satisfy the irrigation demand. The surface watershed directly tributary to the area is limited and the run-off therefrom has been negligible during the past twelve years. Tule River the main stream of the area including South Folk had a mean daily flow of but 112 second-feet as against 272 second-feet for the period 1905–06 through 1916–17. The average depth of the water table below ground over the absorptive area considered, based on the 1929 level, is 56 feet, allowing 46 feet of storage space between elevations ten feet below ground surface and present water level. Upon this basis 2,224,000 acre-feet of storage space are available. Pumping lifts of 100 feet are not uncommon in portions of the present developed area.

Hydrographic Division 3. The modern alluvial fan of the Kaweah River merges with that of the Tule River on the south and the Kings River on the west and provides a highly absorptive body of material having a surface area of 308,000 acres. It is bordered on the east and northeast by an area comprised of older alluvium covered with modern alluvial veneer derived from Cottonwood, Yokohl and Lewis creeks and minor streams which is limited in thickness and width. The water table level in these border areas has been drawn down, during the past twelve years, to elevations requiring high pumping lifts. Little replacement can be exercised locally, but water supplies can be stored underground in contiguous areas of more favorable character and drawn upon to serve the less favorable. Surface irrigation has maintained a relatively high water table over that portion of the area bordering the major streams and covered by the principal or first right canal systems. Southwest of this area, irrigation draft has effected a considerable lowering since 1917. The mean daily flow of the Kaweah River for the twelve years, 1905–06 through 1916–17, during which ground water accumulation was had, equalled 707 second-feet. For the twelve year period subsequent to 1917 the mean daily flow dropped 40 per cent to 424 second feet. The average water level, as of 1929, was 36 feet below ground surface, representing a storage capacity to elevations ten feet below ground surface of 1,212,000 acre-feet. An additional lowering of 20 to 25 feet, on the average, provided replacement provisions are carried on to assure somewhat average conditions throughout the area, could be accomplished if such be necessary to meet the requirements of a 100 per cent supply or complete ground water conservation.

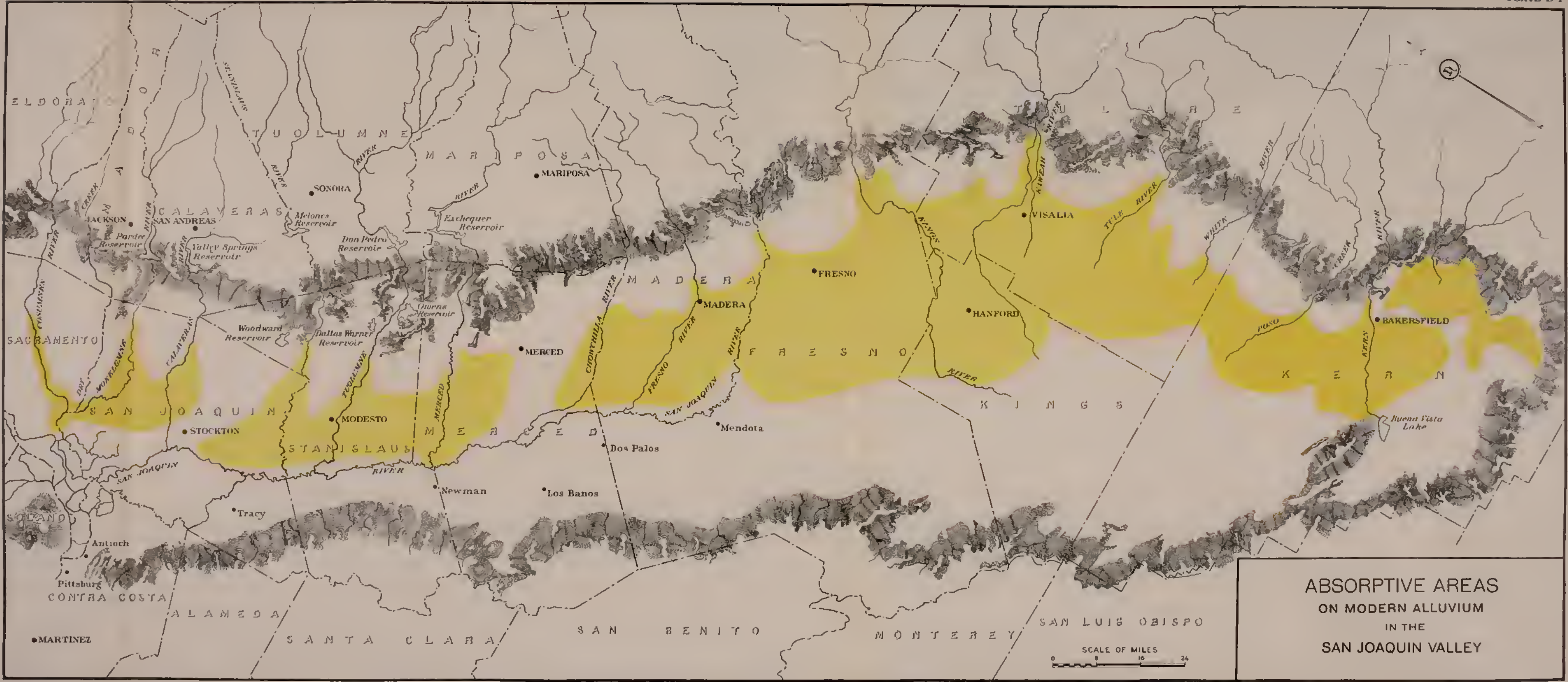
The balance within the area could be maintained by the establishment of well fields at points particularly favorable as to ground water storage capacity, accessibility to surface sources for replenishment, low land value and proximity to point of use. Four such local areas have

trenches and form underflow conduits previously described. The well logs of the area show the modern alluvial fan of Tule River and the accumulation of sediments bordering the Tulare Lake bed to have attained sufficient thickness to constitute an important ground water reservoir. Taking into consideration all types of ground water containers, the surface area totals 322,000 acres.

The greatest water table lowering during the past twelve years occurred over those portions of the area where the water entrapped in the older sediments, which are not subject to ready replenishment, has been withdrawn. Such areas will have to be served surface water to satisfy the irrigation demand. The surface watershed directly tributary to the area is limited and the run-off therefrom has been negligible during the past twelve years. Tule River the main stream of the area including South Folk had a mean daily flow of but 112 second-feet as against 272 second-feet for the period 1905–06 through 1916–17. The average depth of the water table below ground over the absorptive area considered, based on the 1929 level, is 56 feet, allowing 46 feet of storage space between elevations ten feet below ground surface and present water level. Upon this basis 2,224,000 acre-feet of storage space are available. Pumping lifts of 100 feet are not uncommon in portions of the present developed area.

Hydrographic Division 3. The modern alluvial fan of the Kaweah River merges with that of the Tule River on the south and the Kings River on the west and provides a highly absorptive body of material having a surface area of 308,000 acres. It is bordered on the east and northeast by an area comprised of older alluvium covered with modern alluvial veneer derived from Cottonwood, Yokohl and Lewis creeks and minor streams which is limited in thickness and width. The water table level in these border areas has been drawn down, during the past twelve years, to elevations requiring high pumping lifts. Little replacement can be exercised locally, but water supplies can be stored underground in contiguous areas of more favorable character and drawn upon to serve the less favorable. Surface irrigation has maintained a relatively high water table over that portion of the area bordering the major streams and covered by the principal or first right canal systems. Southwest of this area, irrigation draft has effected a considerable lowering since 1917. The mean daily flow of the Kaweah River for the twelve years, 1905–06 through 1916–17, during which ground water accumulation was had, equalled 707 second-feet. For the twelve year period subsequent to 1917 the mean daily flow dropped 40 per cent to 424 second feet. The average water level, as of 1929, was 36 feet below ground surface, representing a storage capacity to elevations ten feet below ground surface of 1,212,000 acre-feet. An additional lowering of 20 to 25 feet, on the average, provided replacement provisions are carried on to assure somewhat average conditions throughout the area, could be accomplished if such be necessary to meet the requirements of a 100 per cent supply or complete ground water conservation.

The balance within the area could be maintained by the establishment of well fields at points particularly favorable as to ground water storage capacity, accessibility to surface sources for replenishment, low land value and proximity to point of use. Four such local areas have


ABSORPTIVE AREAS
ON MODERN ALLUVIUM
IN THE
SAN JOAQUIN VALLEY
SCALE OF MILES
0 8 16 24
ELDORADO
AMADOR
CALAVERAS
TUOLUMNE
MARIPOSA
MADERA
FRESNO
TULARE
KINGS
KERN
SACRAMENTO
SAN JOAQUIN
STANISLAUS
MERCED
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
SAN BENITO
MONTEREY
SAN LUIS OBISPO
JACKSON
SAN ANDREAS
SONORA
MARIPOSA
Pardee Reservoir
Valley Springs Reservoir
Melones Reservoir
Don Pedro Reservoir
Exchequer Reservoir
Woodward Reservoir
Dallas Warner Reservoir
Owens Reservoir
STOCKTON
MODESTO
MERCED
MADERA
FRESNO
VISALIA
HANFORD
BAKERSFIELD
Mendota
Dos Palos
Los Banos
Newman
Tracy
Antioch
Pittsburg
MARTINEZ
Buena Vista Lake
COSUMNES RIVER
DRY CREEK
MOKELUMNE RIVER
CALAVERAS RIVER
STANISLAUS RIVER
TUOLUMNE RIVER
MERCED RIVER
CHOWCHILLA RIVER
FRESNO RIVER
SAN JOAQUIN RIVER
KINGS RIVER
KAWEAH RIVER
TULE RIVER
WHITE RIVER
POSO CREEK
KERN RIVER

80997

been examined on the ground. In addition thereto balance could be maintained by the diversion and spreading of surface water during times of excess flow over areas of heavy irrigation draft, and the pumping of irrigation water from ground water sources, over the area served by canals and ditches during the latter part of the irrigation season, could be practiced in order to maintain the water table below ten feet from ground surface as a drainage and conservation measure. The ground water stood at less than six feet below ground surface for the summer months of 1917 over an area of about 130,000 acres. The ground water discharge or wastage through evaporation probably equalled 150,000 acre-feet with accompanying alkali concentration.

Hydrographic Division 4. The Kings River delta merges with that of the San Joaquin River and is bordered on the east by more indurated materials. The physiographic and ground water conditions of this division are very similar to Division 3 and present the same problems as to maintenance of ground water balance. In 1917 the water table stood less than six feet below ground surface over a large portion of the area. Ground water discharge through evaporation from moist soils allowed wastage of large volumes of water and concentrated alakali salts in the top soil. The lowering of the water table to 1929 levels has rectified this condition somewhat, but lowering to greater depths below ground surface in certain areas would be beneficial and allow for more complete conservation of water through underground storage.

The total absorptive area in the division is 996,000 acres. The average water table level (1929) is but seventeen feet below ground surface. The ground water storage available under present conditions is limited to 1,097,000 acre-feet. The Kings and San Joaquin rivers provide large quantities of stream flow during wet cycles, the mean daily flow of Kings River for the period 1905–06 through 1916–17 being 3000 second-feet. The mean daily flow during the period of water level recession, 1917–18 through 1928–29, was 1800 second-feet about 60 per cent of the preceding period of the same length. In order

TABLE B-2

STORAGE CAPACITIES OF GROUND WATER RESERVOIRS IN HYDROGRAPHIC DIVISIONS 1 TO 4, INCLUSIVE, UPPER SAN JOAQUIN VALLEY

Hydrographic Division	Gross absorptive area, in acres	Estimated drainage factor, in per cent	Depth of storage space, in feet		Storage capacity, in acre-feet	
			Between elevations 10 feet below ground surface and 1929 water levels	Between elevations 10 feet below ground surface and assumed limits of pumping	Between elevations 10 feet below ground surface and 1929 water levels	Between elevations 10 feet below ground surface and assumed limits of pumping
1	525,000	15 and 12½	*	50	**3,707,000	3,750,000
2	322,000	15	46	76	2,224,000	3,650,000
3	308,000	15	26	50	1,212,000	2,300,000
4	996,000	15	7	53	1,097,000	8,000,000
Totals	2,151,000				8,240,000	17,700,000

*Not determined.
**Estimated.

to effect conservation or provide for 100 per cent irrigation supply, ground water draft to the extent necessary to pull down the water table to an average depth of 50 to 60 feet below ground surface may be warranted at the end of a long dry period.

San Joaquin River Drainage Area—Divisions 6 to 12, inclusive.

Divisions 7 and 10 lie west of the San Joaquin River, the region previously eliminated from consideration as ground water storage areas. The divisions lying east of the San Joaquin River can be subdivided physiographically into uplands, modern alluvial fans, valley trough plains and swamp and overflow areas. Of these subdivisions the modern alluvial fans and plains comprise areas over which the surface and subsurface soil materials have the requisite characteristics in relation to absorption and transmission of water which make them ground water reservoirs of economic importance.

The upland areas are the higher lying lands bordering and making up the low foothills of the Sierra. Considerable portions thereof are of alluvial origin, but have become somewhat indurated through age so that much of the rainfall upon its surface is shed, this run-off in turn developing drainage patterns through erosion and filling or covering depressions on border lands with a thin veneer of relatively fine textured modern sediments reworked from the older alluvium. The latter are limited in depth and width and, while comprising local absorptive areas subject to replenishment, they are not important in relation to the broad extent of the uplands.

The older alluvium making up the ancient stream deltas contains ground water derived from the streams that laid them down and held them as the formation became indurated. Furthermore, irrigation activities during the past 25 years have caused the water table beneath these lands to rise from 15 to 50 feet through slow absorption. Ground water has thus accumulated in storage over the period. However, wells drilled in the uplands generally yield water derived through slow drainage of communicating permeable members at relatively low rates, and the stored ground water is soon exhausted when heavily drawn upon for irrigation supply. It is not subject to ready lateral replenishment because of the low transmissibility of the media. Hardpan and compact clayey material is prevalent in the surface soil and causes the water applied to or falling upon the surface in quantity, to be shed rather than absorbed so that ready recharge can not be accomplished.

The valley trough plain is to a large extent lacustrine in origin. It consists of absorptive top soils, with interbedded sand and clay to great depths. The clay members take up a sufficient portion of the soil column to reduce the drainage factor. They also prevent ready recharge from the surface. There exists, however, lateral replenishment to some extent. The fact that this area was formerly one of artesian flow and that the artesian water levels have lowered, although the water level over higher lying lands has risen or remains the same, indicates lateral replenishment is at rates less than the rate of pumping draft. Artesian conditions will only be restored with lateral replenishment in excess of draft for a relatively long period.

The surface topography of the immediate valley trough is that produced by swamp and overflow conditions. The surface soils range from adobe to clay loam. Ground water is near the surface, but difficult to extract from the heavy fine material. Along the borders of this area wells penetrate few sand strata imbedded in dark clays. On the whole the swamp and overflow areas, which includes the delta island region at the northerly end of the valley, are to be eliminated from consideration as ground water storage reservoirs.

Hydrographic Division 6. Division 6 lies between the Chowchilla and San Joaquin rivers in the region covered largely by the Madera Irrigation District. The Madera type soils predominate, but the hardpan characteristics of the type are limited to the top soil and not extensive enough to render it nonabsorptive. Wells of the region, of which there are about 750 producing between 1200 and 1800 gallons of water per minute for irrigation supplies, penetrate sand and clay strata and are landed at about a depth of 200 feet. There were about 81,000 acres of land, in the absorptive area of this division, irrigated in 1929, chiefly by pumping from ground water. This area has a total seasonal water requirement of about 200,000 acre-feet, an amount equal to nearly twice the natural ground water replenishment, for the period of ground water record, with the result that the water level has been dropping an average of one and four-tenths feet per year since 1920. The water table of the fall of 1929 varied from five to 75 feet below ground surface, with an average depth of 35 feet below ground surface over the absorptive area. The surface extent of the absorptive area is 281,000 acres. The ground water storage capacity available between the 1929 water level and an average level 10 feet below ground surface, on the basis of an 18 per cent drainage factor is 760,000 acre-feet.

Pumping lifts of 75 feet now prevail over portions of the area. The utilization of the ground water storage capacity presupposses the recharge of that capacity by spreading of surface water in periods of excess run-off.

Hydrographic Division 8. Division 8 is bounded by the Chowchilla, San Joaquin and Merced rivers, its absorptive area, however, being limited to 146,000 acres. The Merced Irrigation District includes an area of 190,000 acres. A large part of the area is nonabsorptive. Over a portion of this, the excess irrigation water applied to the surface has raised the general water table to close to the ground surface and locally hardpan conditions have caused the swamping of lands by holding water perched above the general water table. Pumping for drainage in this area is being practiced with varying results, one well yielding 800 gallons of water per minute and having an effective radius of about one-eighth mile. Ground water balance over the nonabsorptive areas can be better maintained through control of surface water allotments to that necessary to produce crops without excessive waste. Considering the irrigation district as a whole, the depth to ground water has averaged four and five-tenths feet below ground surface in 1927, five feet in 1923 and five and four-tenths feet in 1929. In 1929 about 80,000 acre-feet of water were pumped from drain wells and it is estimated that 90,000 acre-feet was pumped in 1930.

The Merced District has a regulated irrigation supply with surface storage. Utilization of ground water storage is necessary as a protective measure if not for conservation. In 1927 when ground water stood at its peak for the season, about 80,000 acres south of Merced and west of the Santa Fe Railroad required drainage. Ground water stood from three to five feet below the surface over an area of about 35,000 acres and less than three feet from the surface over about 10,000 acres. The area sufficiently impregnated with alkali to affect crop production is about 5000 acres. This condition has been greatly improved by expansion of the drainage well system. The surface extent of the absorptive area having an estimated 15 per cent drainage factor totals 129,000 acres and 17,000 acres lie within the estimated 10 per cent drainage factor area. Under present ground water conditions the available ground water storage capacity is charged. With the present irrigation practice a pump extraction sufficient to lower the water table to eight feet below ground surface and maintain present drainage would require a rate of approximately 115,000 acre-feet per year for three years.

Hydrographic Division 9. Division 9 comprises the area lying between the Stanislaus, San Joaquin and Merced rivers which is served by the Modesto and Turlock Irrigation Districts. These districts also have a regulated irrigation supply. The control of irrigation deliveries is better practiced and less wastage of water is had than over the Merced district. During the summer of 1917 the water table stood at less than six feet (with an average of four) below ground surface over the irrigated area. Natural drainage is had through the Merced, Tuolumne, Stanislaus and San Joaquin river channels. Pumped drainage also is practiced. The Turlock district, having the greater number of wells, pumped 84,400 acre-feet of water during 1929 and obtained an average water table six and one-half feet below ground surface in the fall of that year.

The surface extent of the absorptive area of the division is 198,000 acres having an estimated 15 per cent drainage factor and 17,000 acres with an estimated 10 per cent. Under present water table conditions ground water storage is filled. In the Turlock district during the 1929 season, a gross surface diversion of 443,000 acre-feet of surface water served 134,000 acres of land. Of the quantity diverted, there was an evaporation loss of 9000 acre-feet in the distribution reservoir. The return flow was 159,000 acre-feet. The total net contribution was 275,000 acre-feet or 2.06 acre-feet per net acre irrigated. There was an average rise in ground water during this period of 0.7 feet. An average seasonal inflow of 1.9 acre-feet per acre irrigated would maintain a stable ground water level. Conservation could be effected by drawing upon ground water to meet the peak irrigation demand in amounts sufficient to maintain the water table below a level eight to ten feet below ground surface.

Hydrographic Division 11. The absorptive area of division 11 consists of the modern alluvial fan of the Stanislaus River, having a surface extent of 83,000 acres, of which 15,000 acres are estimated to have a lesser (10 per cent) drainage factor. The South San Joaquin Irrigation District has a gross area of 71,000 acres of which 54,000 acres were irrigated in 1929. In addition, 14,000 acres of nonirrigated crops received some subirrigation. The diversions into the district totaled about 225,000 acre-feet. In addition about 50 drainage wells were operated and the discharge added to the irrigation deliveries. It is estimated that the return flow was about 90,000 acre-feet, leaving 135,000 acre-feet of water to serve crop needs, be lost through evaporation and effect a net contribution to ground water. The water table has been relatively high over the district since irrigation was inaugurated and protection and conservation warrants a heavy draft upon ground water during the irrigation season.

Hydrographic Division 12. Division 12 includes the flood plains of the Mokelumne and Calaveras rivers, the absorptive area of which covers 104,000 acres. Tests made in the Mokelumne area give, as an average result, a drainage factor of about 10 per cent. The division is similar to No. 6, the Madera area, in that its irrigation supply is derived largely from ground water. Pumping draft has been in excess of replenishment, with a resultant water table lowering on the average of about one and one-half feet per year since 1920. The average water table in the fall of 1929 was 25 feet below ground surface. The ground water storage capacity between the 1929 water level and a level 10 feet below ground surface equals 160,000 acre-feet.

Summary of Hydrographic Divisions 6 to 12, Inclusive. Ground water storage capacity over the greater portion of the area is charged, under existing conditions of irrigation development, and can only be made available with the lowering of the water table through pumping draft. Pumping is now practiced for drainage purposes, but not to the extent necessary to create ground water storage which can be considered of cyclic value. The total use of the surface water available in the ultimate development of the irrigable lands would probably necessitate some draft from the ground water storage of these areas. Upon the basis of 40 feet of lowering below the 1929 water table level at the end of a dry cycle, considerable ground water storage can be made available and is so noted in the general summary.

TABLE B-3

STORAGE CAPACITIES OF GROUND WATER RESERVOIRS IN HYDROGRAPHIC DIVISIONS 6 TO 13, INCLUSIVE, SAN JOAQUIN VALLEY

Hydrographic Division	Gross absorptive area, in acres	Estimated drainage factor, in per cent	Depth of storage space, in feet		Storage capacity, in acre-feet	
			Between elevations 10 feet below ground surface and 1929 water levels	Between elevations 10 feet below ground surface and assumed limits of pumping	Between elevations 10 feet below ground surface and 1929 water levels	Between elevations 10 feet below ground surface and assumed limits of pumping
6	281,000	18	15.0	45.5	760,000	2,300,000
8	129,000	15				
	17,000	10	0	40.0	0	850,000
9	198,000	15				
	17,000	10	0	40.0	0	1,260,000
11	68,000	15				
	15,000	10	0	40.0	0	470,000
12	104,000	10	15.4	50.0	160,000	520,000
13	*10,000	10				
Totals	839,000				920,000	5,400,000

*Along stream channel not utilizable for ground water storage.

TABLE B-4

SUMMARY OF STORAGE CAPACITIES OF GROUND WATER RESERVOIRS, SAN JOAQUIN VALLEY

Hydrographic Division	Gross absorptive area, in acres	Storage capacity, in acre-feet	
		Between elevations 10 feet below ground surface and 1929 water levels	Between elevations 10 feet below ground surface and assumed limits of pumping
1	525,000	[1]3,707,000	3,750,000
2	322,000	2,224,000	3,650,000
3	308,000	1,212,000	2,300,000
4	996,000	1,097,000	8,000,000
5	----------	----------	----------
6	281,000	760,000	2,300,000
7	----------	----------	----------
8	146,000	0	850,000
9	215,000	0	1,260,000
10	----------	----------	----------
11	83,000	0	470,000
12	104,000	160,000	520,000
13	[2]10,000	----------	----------
Totals	2,990,000	9,160,000	23,100,000

[1] Estimated.
[2] Along stream channel; not utilizable for ground water storage.

The data in the foregoing table reveal that the greater surface extent of absorptive lands and consequently the greater ground water storage capacity lie in the upper San Joaquin Valley or Tulare Lake Drainage Area. However, there is a deficiency of run-off in the upper San Joaquin Valley with which to charge this capacity, and while the lower San Joaquin has an excess surface run-off above that necessary to serve irrigable lands with which to charge ground water storage, storage capacity does not exist under present ground water conditions in divisions 8, 9 and 11. The ultimate development of all irrigable lands in the San Joaquin Valley will require the absorption of excess run-off (above irrigation demand) into ground water storage and draft from ground water during periods of deficient run-off in order to meet the irrigation demand.

APPENDIX C

GEOLOGICAL REPORTS ON DAM SITES IN SAN JOAQUIN RIVER BASIN

by

Hyde Forbes

Engineer Geologist

December, 1930

TABLE OF CONTENTS

GEOLOGIC REPORTS ON DAM SITES IN SAN JOAQUIN RIVER BASIN

NASHVILLE DAM SITE ON COSUMNES RIVER
AND
MELONES DAM SITE ON STANISLAUS RIVER

The object of the investigation of the Nashville dam site on the Cosumnes River and the Melones dam site on the Stanislaus River, the general topographic and geologic features of which are shown on Plates C-I and C-II, was to determine the general feasibility of constructing relatively high dams (270 feet at Nashville and 460 feet at Melones) at these sites or to locate more favorable sites in the vicinity and estimate the stripping necessary for consideration in preliminary estimates of cost. No exploration was had at either site, nor was the geology mapped in detail. Sufficient observation was made to cover the object stated, that is, to determine the kind of rock occurring at the dam sites, how it originated, its present position and strength, its structural weaknesses and the effect of weathering upon it.

Geography and Topography.

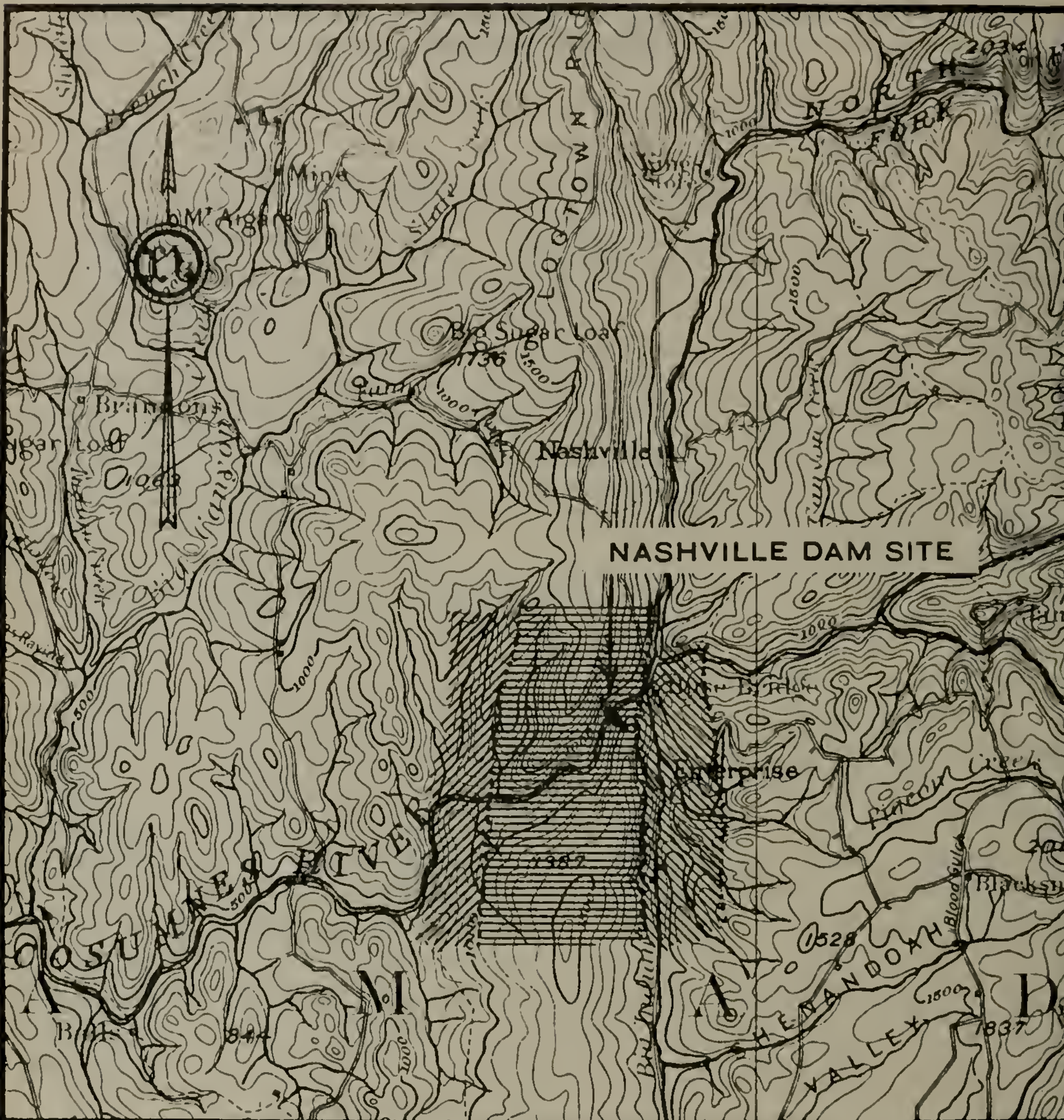
The dam sites examined lie in the Gold Belt of California, the Nashville site upon the Cosumnes River five miles north of Plymouth and the Melones site upon the Stanislaus River eight miles south of Angels Camp. The topographic and geologic features at both sites are similar. Drainage has developed topographic ridges and draws striking northwest-southeast and controlled by the prevalence of bands of rock varying in hardness and resistance to erosion. The drainage joins to form the major streams which have cut gorges across the strike of the resistant rock ridges in attaining a westerly course. This gorge development provides dam sites with reasonable crest lengths for proposed heights above stream beds of the dams under consideration.

General Geology.

The Sierran bedrock complex (so called in the U. S. Geological Survey folios) attains its greatest complexity in the Gold Belt. It is described by F. L. Ransome, geologist, in Folio 63 as follows:

"The bedrock complex consists of both sedimentary and igneous rocks. The sedimentary rocks were originally beds of mud, sand and gravel. They represent the mechanical waste of ancient land surfaces which were long ago deformed and have been carved by erosion into new forms or buried under later sediments and perhaps partly fused by invading, deep-seated igneous intrusions. The sediments derived from this old land mass remain, but the land mass itself has disappeared during the slow progress of geological change. Carried down by the streams, this material was spread by waves and currents over the sea bottom in nearly horizontal layers. There were periods of volcanic activity during the deposition of these early sediments. Igneous material, thrown out either as loose fragments or as volcanic mud, was also spread over the sea bottom, accompanied probably by flows of molten lava. These beds and the associated volcanic rocks have been folded and compressed chiefly in a northeast-southwest direction, and have been irregularly introduced by masses of igneous rocks, such as granite, diorite and gabbro. The sediments have been hardened and changed by the long-continued action of underground solutions, the pressure and movement of folding, and the heat of igneous intrusions until they often bear no resemblance to their original condition. The bedrock complex is therefore made up of both sedimentary and igneous rocks. It is an intricate assemblage of many different kinds of rocks, differing considerably in age. It contains probably more than one sedimentary series, as that term is commonly used in geology. For these reasons it seems best to speak of it as a complex."

PLATE C-I



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
NASHVILLE DAM SITE
ON
COSUMNES RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Calaveras formation

Diabase

Mariposa formation

PLATE C–II

GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
MELONES DAM SITE
ON
STANISLAUS RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Diabase

In the vicinity of the dam sites the rocks of sedimentary origin consist of a body of grey colored clay slates, with well defined cleavage planes which may or may not conform to the original bedding planes. At the Nashville site the contact between the slates and the rock of igneous origin lying downstream therefrom is fairly well marked. At the Melones dam site the slates grade downstream into thin bedded rock, which probably originated as tuff, and more massive rock is found farther down stream through Iron Canyon.

The rocks of igneous origin have undergone considerable alteration due to the stresses to which they have been subjected and the passage of gasses and solutions through them. The metamorphism is profound and has resulted in hard crystalline rock masses, which have been designated diabase and porphyrite in previous reports, following the terminology used in the early reports of the United States Geological Survey. The term diabase includes original beds of loosely consolidated tuff and volcanic breccia, which have been altered by the development of secondary green basic minerals so that the whole has been converted into hard crystalline rock, as well as the more massive eruptive or intrusive green rock containing small crystals of augite and magnetite in a glassy ground mass.

Geologic Structure.

In common with other Sierran regions, the original rock masses here have been folded and compressed into bands which strike northwest-southeast. The stresses were so intense that the sedimentary rocks were altered to slates and schists in which were developed cleavage and schistocity planes along which the rocks part readily into thin slabs or plates. The same stresses transformed the volcanic tuff beds into somewhat thicker schistose bands and the extrusive or intrusive rocks into more massive bands of rock. Such open joints and faults as developed during the period of folding have been closed and healed by the deposition of secondary quartz so the mass at reasonable depth below ground surface is sound. Subsequent crustal movement developed stresses which caused the mass to joint without parting or movement of the joint walls. No active faults are known.

Nashville Dam Site.

Big Indian Creek and the North Fork of the Cosumnes River have eroded their gorges along the contact between a grey colored slate and a formation of igneous origin. Erosion has carried the stream beds into the slates to their juncture with the South Fork, where they turn at right angles to traverse the igneous rock. At the contact, the igneous rock is a coarse textured green rock containing large tabular crystals of augite and hornblende, termed porphyrite. This continues downstream for about 500 feet, becoming finer textured until it merges with a close textured green rock diabase, consisting of small crystals of augite and magnetite in a glassy ground mass. The diabase is a more resistant hard rock and the stream through it has cut a narrow "V" shaped gorge with cliff profile to 125 feet above stream bed. The site is entirely satisfactory, from both geologic and topographic considerations, for a high concrete structure.

The igneous rocks probably originated as flows over the surface of clay shale. The series of formations later were subjected to folding and distortion accompanied by intense pressures. These dynamic forces caused a hardening of the shale into slates, and recrystallization and hardening of the igneous series resulted in the present rock forms. The stresses caused the diabase and porphyrite to become banded, with the bands striking north 40 degrees west across the stream and dipping almost vertically so that the same mass exposed on one abutment continues beneath the stream to great depth and up the opposite abutment and probably for long distances across country.

The massive rock has developed joint systems, the principal jointing striking with the stream south 60 degrees west at right angles to the banding and dipping 65 degrees from the horizontal. An intersecting joint dipping north 60 degrees east about 80 degrees and a horizontal joint dipping due south about 10 degrees are the other main joints. Minor joints have developed in loose joint blocks, but are not profound features continuous in the mass.

This jointing has weakened the mass so that, while rock appears continuously up both abutments, outcrops are joint blocks loosened from the mass. Their removal and the removal of underlying loose blocks probably would necessitate an average depth of stripping of 20 feet on the right abutment and 25 feet on the left. The joints are structural features which persist to great depth, but should be found closed and relatively tight at these distances below ground surface. The joint walls are sound and, should they be found to part, could be closed with grout. The stream bed consists of fresh water-worn and potholed bed rock, which probably would have to be cut into an average of ten feet to produce an even surface and key in the structure. The joints in the fresh rock in stream bed are closed tight features and probably would refuse grout.

There is no suitable construction material available at or in the immediate vicinity of the dam site. The spillway should be provided over the structure, preferably in the center, to discharge to stream bed over the fresh sound rock in the channel.

Melones Dam Site.

The topographic and geologic features at the Melones dam site are a duplicate of those existing at the Nashville site. The northwest-southeast drainage has developed along the contact between slate and altered rocks of igneous origin. This drainage joins and passes southwest across a more massive diabase in which it has eroded a deep narrow gorge.

The site proposed for a high dam lies between an eighth and a quarter of a mile downstream from the present dam. It is the best site geologically and topographically in this section of the stream. At this point lies a dike-like rock mass, consisting of a fine grained, dark green diabase which is banded, the bands striking north 40 degrees west across the stream with the trend of the topographic development. The stream has developed a deep "V" shaped gorge with cliff profile (called Iron Canyon) through the mass. The right abutment has rock outcropping to the crest of the ridge with uneven eroded surfaces. The left abutment consists of fairly uniform steps at the lower levels, developed along major joints which dip due west 25 degrees from the horizontal, and an uneven rocky slope to the top. An intersecting joint dipping north 70 degrees east 80 degrees also is well developed, but the multitude of minor joints found upstream are absent from the diabase.

Stripping allowance of fifteen feet on the average at right angles to the slope on the right abutment and 20 feet on the left abutment should provide for the removal of all loose material and reveal rock which, though jointed, could be rendered sound by pressure grouting. The width of the channel at stream bed varies from 30 to 50 feet. It carries some large joint blocks and probably fifteen feet of gravel over a potholed bed rock. The latter site in Iron Canyon fills all the requirements for a high concrete structure.

IONE DAM SITE ON DRY CREEK

The Ione Reservoir would be created by construction of a dam across Dry Creek in the vicinity of Ione. The reservoir area consists of broad valleys and rounded ridges developed by post-Neocene erosion of a gently dipping plane which was the top of an accumulation of sedimentary beds lying along the base of the western foothills of the Sierra Nevada. The sedimentary formation contains but few resistant members, so the dam site available is limited to a relatively wide and heavily alluviated stream flood plain lying between two long ridges.

The site, if occupied by a dam 120 feet high, would necessitate building two auxiliary dams in topographic saddles due north. The reservoir capacity so created would necessitate diversion of Mokelumne River water through a spillway now built as part of the Pardee Dam project in order for it to be utilized to fullest practicable extent.

General Geology.

The geologic development of the western slope of the Sierra Nevada is generally considered to have closed with the cessation of the great volcanic eruptions accompanying the Sierra uplift of Neocene time. During that period the streams were heavily burdened with detritus, chiefly in the form of ash, cinders and bombs of volcanic origin, and often to such extent as to become mud flows. This detritus reached the Tertiary sea, which occupied the great valley depression, was distributed over its bottom in rapid accumulation and was raised above sea level and became hardened as it dried and aged during Pleistocene time. The result was a gently dipping thick series of marine sedimentary beds of tuffaceous and siliceous shales, fine to coarse grained tuffaceous sandstones, conglomeratic sandstone and conglomerate. This series of sediments are contemporaneous with the shore gravel found south and east of the reservoir site and the gold bearing Tertiary stream gravels found at higher elevations. South of the reservoir site the shore and stream gravel is buried beneath a capping of lava and tuff.

Geologic Structure.

The streams, freed of their sediment burden and with steeper gradients, have cut down into the sedimentary formation and developed the existing topography. The topographic expression is the result of differential weathering and erosion upon an almost horizontal series of sediments capped by lava and tuff south of the reservoir site and overlying diabase. No faults were found or are known to exist in the region.

Ione Dam Site.

The general topographic and geologic features in the vicinity of this site are shown on Plate C-III. The sedimentary (Ione) formation at the dam site consists of nearly horizontally stratified fine to coarse grained tuffaceous sandstone beds interbedded with siliceous shale members and conglomerate. The vertical section exposed along the abutment ridge, through which the stream has cut at the dam site, evidences all these phases as the result of the frequency in change of character of detritus carried to the region and changes due to crustal movements in the marginal areas from deep to shallow water and stream deltas. The uppermost bed is a conglomerate carrying water-worn gravel and boulders derived from the older rock of the upper watershed areas, as well as water-worn fragments of lava and pumice. About 75 feet above stream bed a tuffaceous sandstone, consisting of light colored ash and sand, is found on the left abutment, while a coarser grained and darker colored formation of similar character is found on the right abutment. This bed is underlain by a thick conglomerate consisting almost entirely of volcanic fragments, some water-worn, in a matrix of tuffaceous material. Underlying is a thin bed (four to six inches) of siliceous shale topping another sandstone bed which varies from fine to coarse textured and conglomeratic laterally and vertically down to stream bed elevation.

The cementation varies widely, some portions being difficult to break with a hammer, and upon submersion in water, while absorbing water, does not disintegrate or lose particles with rubbing. Other portions are readily broken, absorb water so rapidly upon submersion that it causes heavy effervescence of interstitial air and can be worked down with the fingers. As a whole, the formation is too "spotted" to make a foundation for a concrete structure, but entirely satisfactory for an earthen dam.

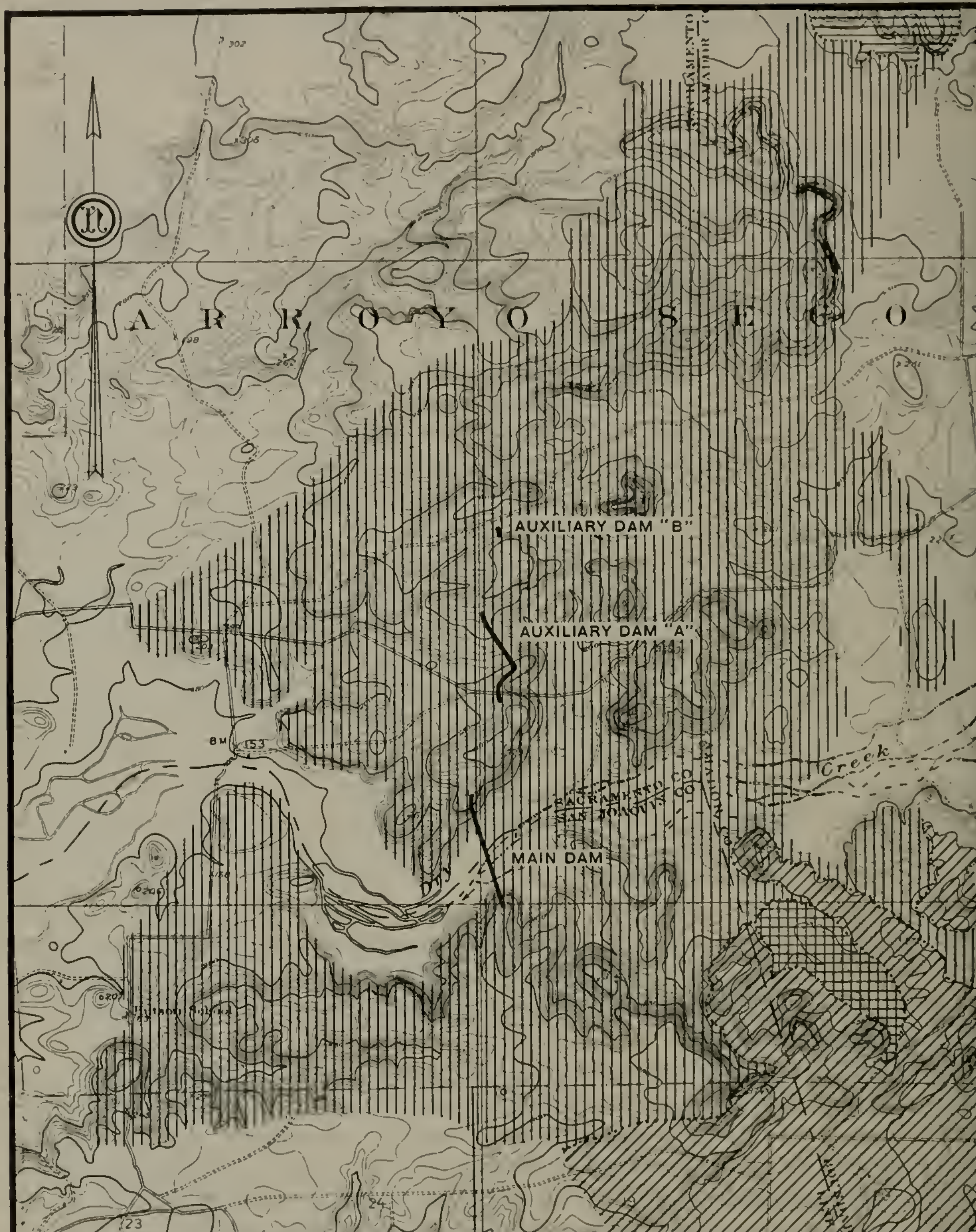
Weathering has attacked the formation with varying results. On the steeper side slopes sound rock is exposed or exists under shallow soil cover. On the upper slopes and crests of ridges a red-brown clay soil containing gravel and cobbles exists, probably at an average depth of ten feet over sound rock. The stream has cut a "U" shaped trench with a fairly wide bottom covered by flood plain material, which probably has an average thickness of 35 feet over sound rock.

Exploration of the dam site was made by Stephen E. Keiffer, consulting engineer. A descriptive log of the holes is appended to this report. Their locations are shown on Plate C-IV. A. Werner Lawson, geologist, reported to Mr. Kieffer of the site and analyzed the cores as follows:

"For the purpose of determining the character of the flat lying strata beneath the valley floor several vertical diamond drill holes were bored into it along the line of the proposed structure. These penetrated the bedrock to a depth of 50 feet beneath the alluvial covering. The cores from the bore-holes show the rocks beneath the valley to be of essentially the same character as those exposed in the sides. They are alternating strata, varying from fine to coarse textured, hard to relatively softer, but firm, well compacted sandstones and dense, well compacted sandy clays.

Owing to the variations in character of the material forming the rocks at the dam site, both in its horizontal and vertical distribution, no large part of the structure will be of the same kind of material, or on the same stratum."

PLATE C–III



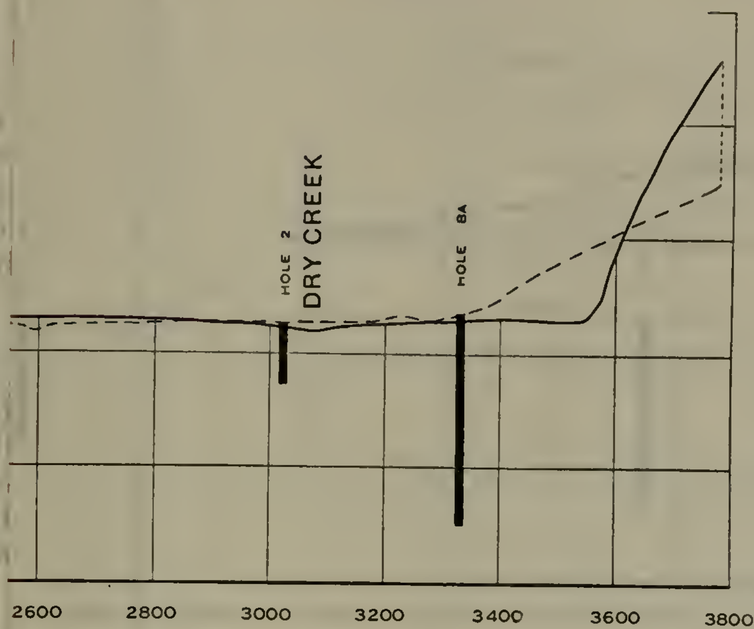
GENERAL TOPOGRAPHIC
AND
GEOLOGIC FEATURES
IN THE VICINITY OF
IONE DAM SITE
ON
DRY CREEK

SCALE OF MILES

0 1 2

LEGEND

- Underlying diabase bedrock complex
- Ione - sandstone - shale conglomerate - tertiary
- Volcanics - lava and tuff - tertiary
- Stream and shore gravels - tertiary



LOCATION OF

DIAMOND DRILL BORINGS

AT

IONE DAM SITE

ON

DRY CREEK

BORINGS MADE IN 1924

PLATE C–III

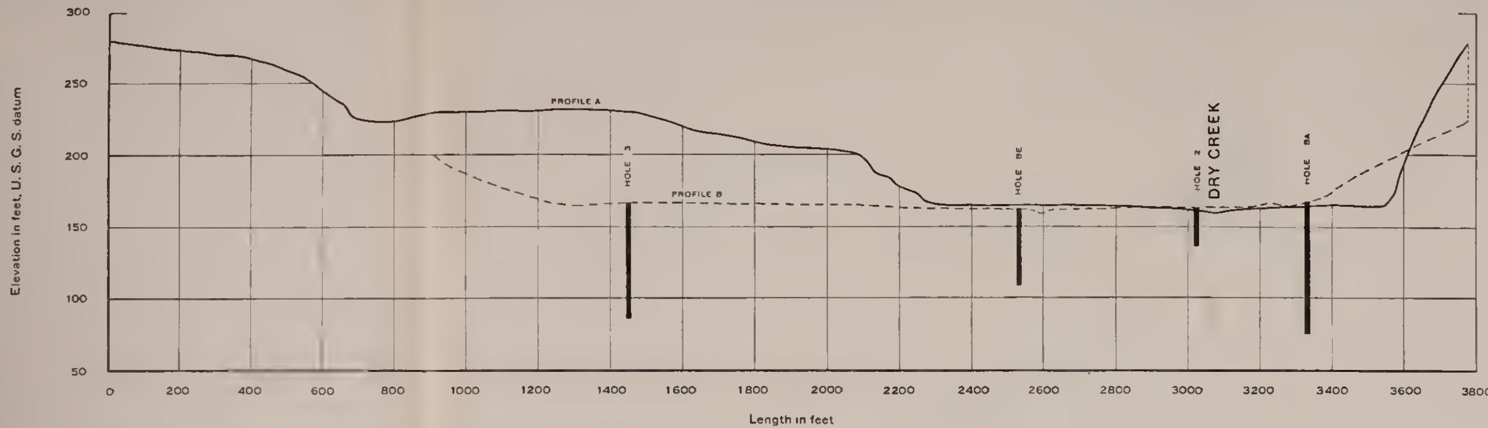
GENERAL TOPOGRAPHIC
AND
GEOLOGIC FEATURES
IN THE VICINITY OF
IONE DAM SITE
ON
DRY CREEK

SCALE OF MILES

0 1 2

LEGEND

- Underlying diabase hedrock complex
- Ione - sandstone - shale conglomerate - tertiary
- Volcanics - lava and tuff - tertiary
- Stream and shore gravels - tertiary



PROFILES A AND B
LOOKING UPSTREAM

PLAN OF DRILL HOLES

FEET
0 400 800

LOCATION OF
DIAMOND DRILL BORINGS
AT
IONE DAM SITE
ON
DRY CREEK
BORINGS MADE IN 1924

Stripping could be limited to the removal of the high humus content soil. A deep cut-off below rock line would be unnecessary. The rock, though porous, is sufficiently fine textured in the sandstone and conglomerate matrix as to be practically impervious. It is too soft to allow open joints to persist.

The gravel and cobble filled clay loam weathering product found capping the ridges is ideal material for rolling in construction of the upstream third of an earth fill dam, and the flood plain alluvium should provide satisfactory material in sufficient quantity for the balance.

The site, with water surface elevation at 270 feet, would require two auxiliary dams. One would have to be about 50 feet high and abut against the same rock series as the upper 50 feet of the main structure, while the other would have to occupy a saddle whose crest is about elevation 265. Rock is close to the surface and would provide sound foundation for a concrete spillway structure which should be provided with a protective apron for several hundred feet downstream.

LOGS OF DIAMOND DRILL BORINGS AT IONE DAM SITE ON DRY CREEK, JANUARY 1924

Depths, in feet	Descriptions of formations and cores
HOLE No. 3—	
0 to 6	Black clay soil with small amount of cobbles and gravel. A three-inch standard pipe was washed down and seated in the sandstone.
6 to 21	Sandstone composed of sand cemented with clay. Core ground up by small gravel.
21 to 26.5	Sandstone. Good core.
26.5 to 31	Sandstone. Core same as above.
31 to 32	Clay.
32 to 38	Sandstone. Core.
38 to 55	Sandstone. Core; decreasing amount of clay.
55 to 63	Partially consolidated sandstone. No core.
63 to 65	Partially consolidated sandstone somewhat harder than 55 to 63. Showed traces of clay. No core.
65 to 80	Partially consolidated sandstone similar to section 55 to 63. No cave in hole and all water returned with pressure of 125 to 175 pounds.
HOLE "B E"—	
0 to 3	Sandy loam.
3 to 15	Close grained clay soil. No water.
15 to 17	Sand and gravel. Water.
17 to 25	"Quick" sand.
25 to 30	Sand and clay.
30 to 40	"Ione" clay.
40 to 42	Clay changing to sandstone.
42 to 51	Sandstone. Good core.
51 to 53	Sandstone. Gravel incorporated with sandstone, making drilling difficult.
HOLE "B A"—	
0 to 27	Silt, sand and clay. Water at eight feet.
27 to 28	Sandstone.
28 to 31	Sandstone, coarse-grained sand and gravel. Had to use chipping bit. Could not use Diamond bit because of gravel.
31 to 36	Sandstone. Small amount of clay. No core.
36 to 41	Sandstone. Very fine grain, with considerable amount of clay.
41 to 46	Sandstone. Good material.
46 to 51	Coarse sandstone.
51 to 56	Sandstone.
56 to 61	Sandstone, decreasing amount of clay. No core.
61 to 66	Similar to 56 to 61. No core.
66 to 76	Sandstone with increasing amount of clay. No core.
76 to 91	Sandstone. Very dense and hard. Good core.
91 to 92	Sandstone with gravel. No core.
HOLE No. 2—	
0 to 26	Sand, clay.
26	Sandstone.

Holes drilled with an "A.S." bit, making a one-inch core.

DON PEDRO DAM SITE ON TUOLUMNE RIVER AND EXCHEQUER DAM SITE ON MERCED RIVER

The object of the investigation of the Don Pedro dam site on the Tuolumne River and the Exchequer dam site on the Merced River, upon which concrete structures have been built, was the determination of the geologic feasibility of raising these structures. The results of previous geological examinations were made available in reports of A. J. Wiley on Don Pedro Dam and that of Herbert N. Witt, consulting geologist, upon the geology and results of diamond drilling of the Exchequer dam site. No additional exploration was had, nor was the geology mapped in detail at either site.

Geography and Topography.

The geography and topography is shown on the Sonora Quadrangle sheet of the U. S. Geological Survey, attached as Plate C-V. The dam sites lie in the stream canyons just above the foothills of the Sierra Nevada, the ridges of the region reaching an altitude of little over 1,000 feet above sea level. At the dam sites the rivers have a southwesterly trend through restricted gorges cut across the northwest-southeasterly trending ridges. Above the dam sites the drainage, for the most part, follows the topographic trend, and wider valleys, which provide reservoir areas of considerable capacity for the height of dam proposed, have developed.

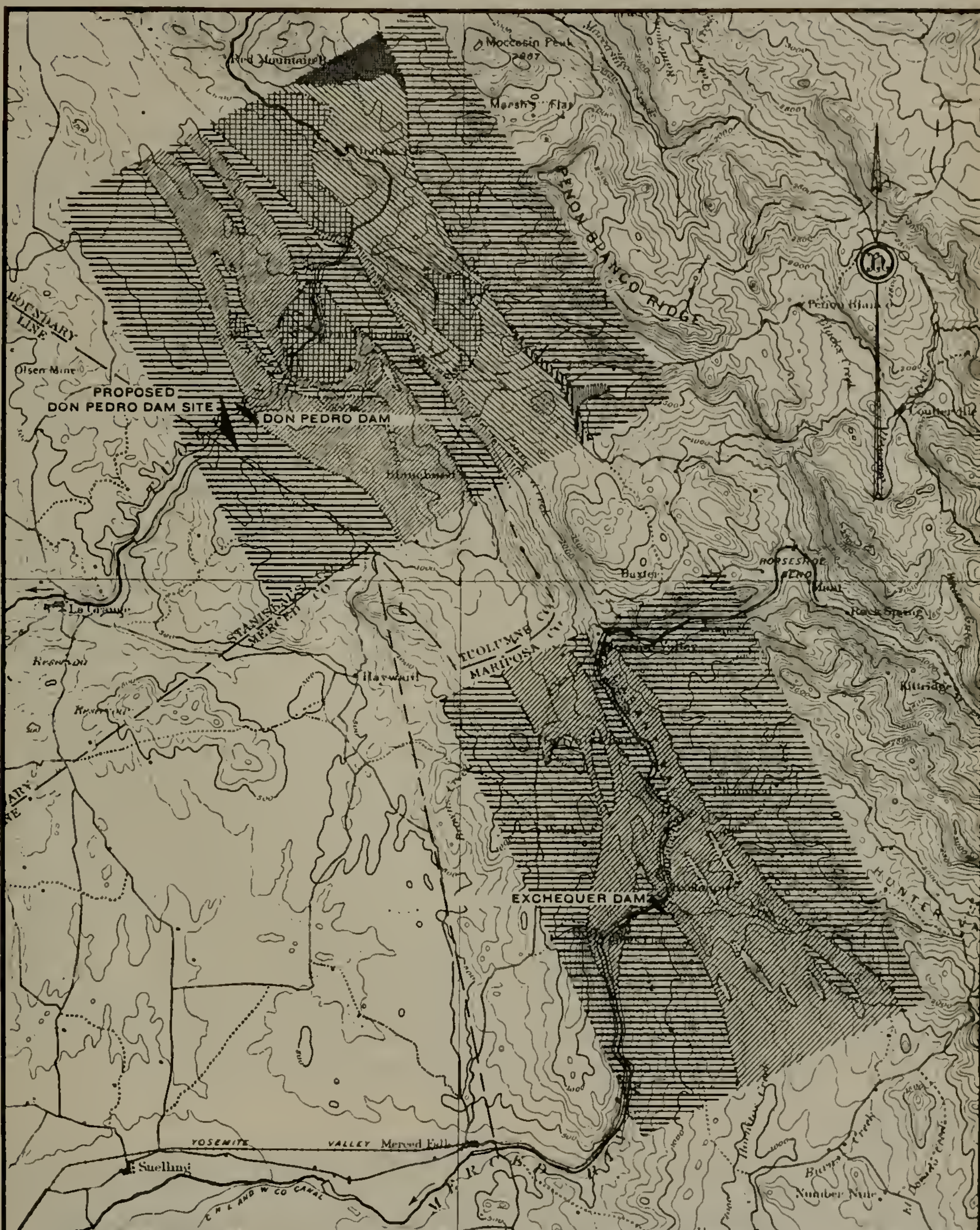
General Geology.

The general geology of the area is published in the Sonora Folio of the U. S. Geological Survey. Briefly, the rocks of the region are of many kinds and occur in complex associations. In origin they are, within relatively short distances, in part sedimentary, in part volcanic, being the products of igneous eruption and extrusion, and in part igneous intrusions. All have subsequently suffered considerable displacement, compression and alteration. The original structure, clastic, fragmental, or massive igneous, as the case may be, is lost in folding and banding, due to compression, and the primary minerals are changed to alteration products through recrystallization under the stresses to which the rock masses were subjected, so that petrographic distinctions are extremely difficult and of little value to the engineer. The principal questions of interest are the soundness of the rock mass and the extent to which weathering has attacked and weakened the rock surfaces.

Don Pedro Dam Site.

The stream gorge, at the upper end of which is constructed the present Don Pedro Dam, begins at the contact between slate and a relatively thin bedded green rock which is probably a metamorphosed tuff. Just below the present dam the rock layers have been sharply folded and somewhat faulted along joint planes. The upstream leg of the fold upon which the dam rests dips more gently. The folding, however, weakened the rock mass to the extent that weathering attacked it and left but a low ridge on the right abutment. Therefore, the topographic development and geologic structure prohibit construction of a higher dam on the site of the present one.

PLATE C–V



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES

IN THE VICINITY OF

DON PEDRO AND EXCHEQUER DAM SITES

ON

TUOLUMNE AND MERCED RIVERS

SCALE OF MILES

0 1 2 3 4 5 6

LEGEND

Shore and river gravels	Grano - diorite and granite
Mariposa formation	Porphyrite
Alluvium	Amphibolite
Serpentine	

The westerly leg of the sharply folded anticline dips more gently progressively downstream and the cross jointing becomes less pronounced. The rock bands become thicker and more resistant to the attack of the weather and erosion, so the canyon walls rise higher.

At a point about one-half mile downstream from the present dam a thick bedded or banded series of rocks strike across the stream. The rock bands are somewhat vesicular at their boundaries and the petrographic characteristics suggest a series of basic lava flows, resembling rocks described in previous reports and termed diabase. The beds or bands dip south 25 degrees west 60 to 65 degrees downstream, or into the earth about 175 feet vertically in every 100 feet horizontally.

The right abutment is somewhat jointed, and probably would require an average stripping depth of ten feet over the stream bed and to the top of the cliff line 150 feet above stream bed and an average of 20 feet from that point to the dam crest in order to remove loose joint blocks and reach reasonably sound rock in which the joints could be pressure grouted. The left abutment carries a heavier soil cover and is somewhat wooded. Rock in place outcrops up a topographic draw, but on the slopes rock is found only as disintegrated joint blocks. Stripping allowance should be 15 feet to 150 feet above stream bed and 25 feet to the crest of the ridge. Two systems of joints are prominent, one following the strike and dipping northeast, intersecting the planes of banding, and the other a nearly vertical joint system cutting obliquely across the strike and along some of which there appears to have been some movement, now long dead. Such faults are healed with quartz, but topographic draws have developed along the fault zones.

In order to take the best advantage of the topographic development, yet conform to the rock structure, the center line of the dam should preferably lie across the strike of the rock bands, where the bands are relatively thick. So laid out, the site would be entirely satisfactory for a concrete gravity or arch type dam.

A spillway could be provided at the left end of the dam crest with but little excavation to control and carry the overflow to the river channel about 1000 feet downstream from the toe of the dam.

There is no suitable construction material available at the site.

Exchequer Dam Site.

The economic advantage of incorporating the present Exchequer Dam in a higher dam may counterbalance the excessive stripping that would be necessary up the right abutment to the top of the ridge.

The rocks of the dam site have been described as the altered volcanics of the Mariposa formation and later granular intrusives. Alteration, however, in places is such that the origin of the rocks is less obscure than any site examined in the Gold Belt. The rocks of the left abutment consist, upstream to downstream, of tuff beds altered to light colored schist and dark green amphibolite schist, with the planes of schistocity striking north 40 to 50 degrees west, and along which the Cotton Creek topographic draw has developed; then a series of ancient andesite breccias and andesite flows in which the alteration varies, but, although hardened and with the original jointing closed and healed through the introduction of secondary quartz, it resembles petrographically the younger and softer Tertiary andesite flows and breccias found in other Sierra regions.

Diamond drill borings in this material resulted in good core recovery and satisfactory pressure tests. Above the crest of the present dam the surface rock is considerably jointed. Stripping allowance of fifteen feet to 700-foot elevation and 25 feet to the proposed dam crest, on the average, over the left abutment should be sufficient.

The right abutment presents a different rock type. The metamorphosed andesite and andesitic breccias found on the left abutment occupy the stream bed and up the right abutment to about the 500-foot contour. Above this is found the metamorphosed basic lava and tuffs previously termed diabase.

The diabase, a massive green rock, is exposed in the old quarry above the right abutment and outcrops at progressively lower elevations over the surface to the present dam. Outcropping above the diabase is another series of metamorphosed andesitic flows and tuffs, somewhat schistose in places. The diabase is a very hard rock and diamond drilling therein produced better than 95 per cent core recovery.

The rock outcropping above, and lying at and above the crest of the right abutment of the present dam, is softer, considerably jointed and weathered more deeply. Furthermore, an old fault, now entirely healed and along which it is unlikely movement will occur in the future, intercepts the right abutment at the crest of the present dam. This fault zone consists of considerably shattered rock in which the joint blocks are displaced.

The diamond drill holes crossing the fault at depth in the gorge lost core at these locations and lost water under pressure test, but not to the extent that grouting could not rectify these difficulties. It is difficult to estimate the distance from ground surface at which sound rock will be found in the shear zone. It is limited in width, but may need as much as 100 feet of excavation. Exploration of this feature should be carried on before any final plans for a higher dam are considered. For preliminary estimate purposes it would be well to allow an average depth of twelve feet stripping to the 700-foot elevation and 60 feet above that on the right abutment.

BUCHANAN DAM SITE ON CHOWCHILLA RIVER AND WINDY GAP DAM SITE ON FRESNO RIVER

The Chowchilla and Fresno rivers drain that portion of the Sierra Nevada watershed tributary to the Madera area of the San Joaquin Valley. The Madera Irrigation District has, in addition to sites on the San Joaquin River previously reported upon, investigated, surveyed and partially explored dam sites on these rivers. That on the Chowchilla River near Buchanan is located in the southeast quarter of Section 20, Township 8 South, Range 18 East, M. D. B. and M., at stream bed elevation 410. The Windy Gap site on the Fresno River lies just downstream from Fresno Flats in the east half of the southeast quarter of Section 2, Township 7 South, Range 20 East, M. D. B. and M. Both sites lie within the area mapped on the Mariposa Quadrangle of the U. S. Geological Survey.

The topographic development of the region is the result of post-Tertiary erosion of the middle western slope of the Sierra Nevada. This erosion has developed drainage patterns which lack the regular arrangement of continuous parallel ridges and draws conforming to the rock structure in the more northerly Sierra regions and the prevailing course of the regional drainage is more south than west in conformance with the inclination given the western slope of the Sierra during late Tertiary time. The region is one of moderate rainfall and neither stream reaches far enough toward the crest to be snow fed in summer, so the stream bed is dry or carrying low flow over considerable stretches for long periods during the year. Atmospheric weathering keeps pace with stream erosion, so that the channels are bordered by gently sloping hills rather than stream cut canyons, the two dam sites occupying the only two exceptions noted.

General Geology.

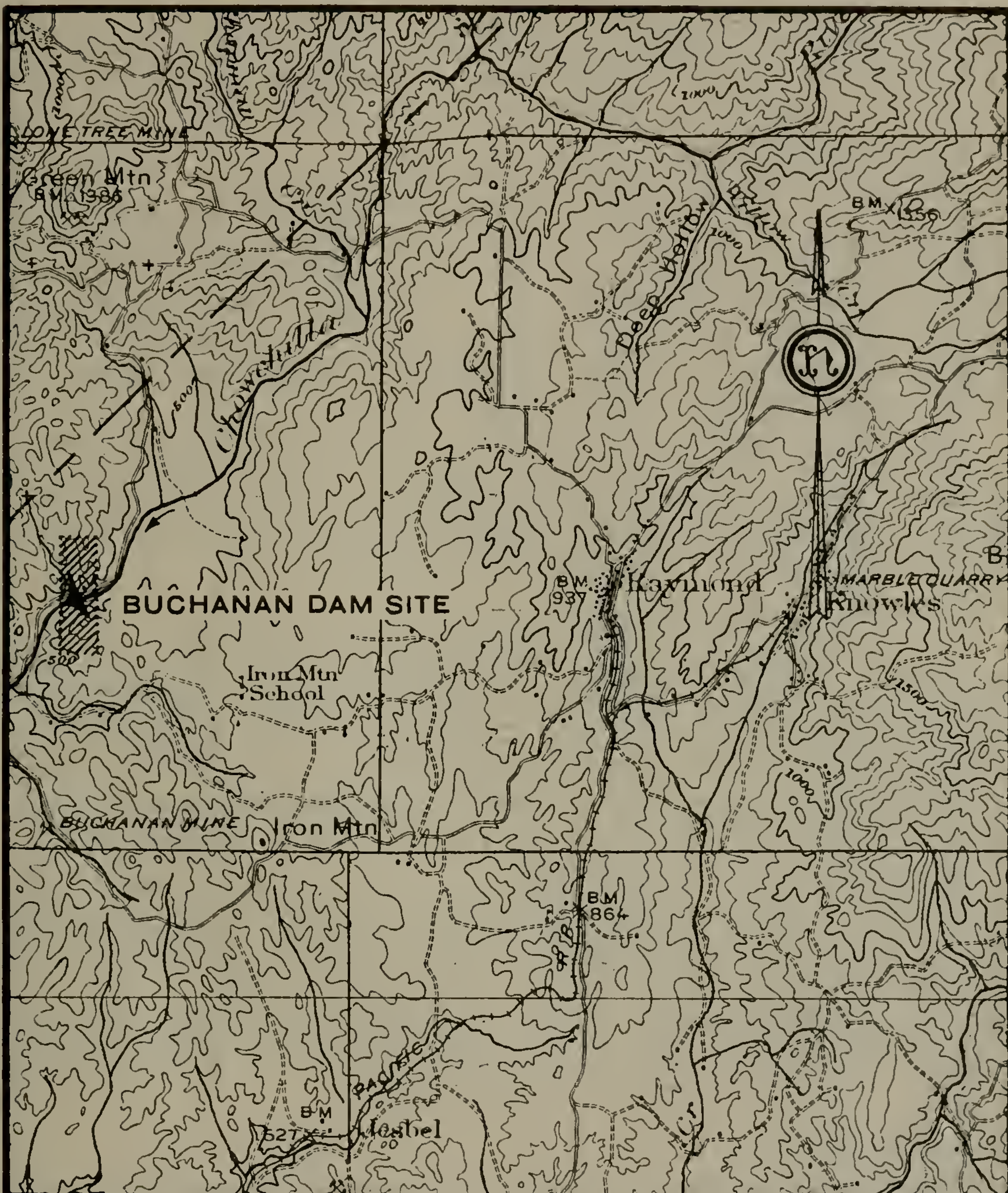
The topographic development is due largely to the character of the bed rock of the region, which consists principally of pre-Jurassic sediments into which granitic rocks have intruded. The original sediments are so altered that they have been rendered crystalline with an increase in hardness. The altered rocks, where examined, consist principally of a black micaceous slate and mica schist. The granites preserve their original structure, texture and mineral constituents, which vary considerably from place to place. The topographic development in the granitic areas has produced rounded hills and the conspicuous ridges are made up of belts of the metamorphic rocks.

Buchanan Dam Site.

The Buchanan Dam site, shown on Plate C-VI, lies at a point where the Chowchilla River has cut through a rock ridge, consisting of mica schist, across the planes of schistocity. The schistose texture is fully developed, due to the alignment of thin sheet crystals of the bronze colored mica-muscovite alternating with sheets of minute quartz crystals. Some facies of the rock contain the smaller crystals of the black mica-biotite and the schistocity is less marked, while others present large inclusions of primary quartz. The whole makes up a hard crystalline rock mass containing lines of weakness or parting planes which strike across the channel and dip north 35 degrees east 75 to 80 degrees from the horizontal upstream.

The site was partially excavated over thirty years ago, revealing the same bands of rock carrying from one abutment across the stream bed and up the opposing abutment. The weathered rock surfaces show parting along the planes of schistocity. In addition, the rock mass has developed three main joints, one dipping north 70 degrees west 80 to 85 degrees from the horizontal, one dipping south 40 degrees west about 18 degrees, and the other dipping south 80 degrees east 40 to 50 degrees, which cause the mass to break into rectangular blocks under weathering at the surface. At fresh exposures in the stream bed, the schistocity planes and joints are closed features. The condition of these lines of weakness below ground surface is revealed by diamond drill borings made for Madera Irrigation District. The locations of borings are

PLATE C–VI



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
BUCHANAN DAM SITE
ON
CHOWCHILLA RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Mica-schist

shown on Plate C-VII, and logs of the holes are given in the table below. The planes and joints appear from the logs to be closed features, except in a limited zone from 45 to 60 feet below stream bed where water was lost. The cores were not examined, but the rock type is such as to contain no joint openings that could not be closed by pressure grouting.

Rock outcrops continuously across the stream bed and an average cut of six feet should be all that would be necessary to even up the rock foundation and key in the structure. The same rock bands extend up both abutments to the crest of the ridge and present the best structure, with planes dipping upstream, for dam foundation. Partial stripping has been done and an average of ten feet additional stripping should be ample provision for sound foundation. Construction material is available in gravel bars above and below the site.

The following data on foundation material including rock classifications and logs of diamond drill borings were obtained from a report by Harry Barnes, Chief Engineer, Madera Irrigation District, who made an inspection of the cores obtained and studied the driller's daily records. Reference is made to four classifications.

ROCK CLASSIFICATIONS BUCHANAN DAM SITE

No. 1—A uniform close grained rock, hardness about five, classed as a mica schist. This rock shows the presence of considerable mica, but it is fairly heavy, compact and homogeneous, cores well and carries no evidence of disintegration or weathering. In places this schistose rock shades almost into a gneiss or granite, and occasionally may include a seam of very hard, compact and almost non-crystalline rock. It was the aim to carry each hole down until rock of this character was encountered.

No. 2—Mica schist, hardness about four. Coarser grained than No. 1, streaked with rust and may contain narrow seams or sheets of oxide with a general discoloration thereof. On the whole a fairly compact hard rock that cores well, but cores inclined to break where rust streaks occur.

No. 3—Soft, coarse, micaceous sandy rock. Much of this rock seems like a rotten sandstone, possesses laminations but no cleavage, and can be easily broken with the fingers. Yellow oxide streaks occur throughout, the rock being relatively light and apparently more or less porous. In some the mica occurs as rather large flakes, in other pieces it is almost microscopic, being practically a micaceous sand. Short cores obtainable, but easily broken or ground up by the bits.

No. 4—Includes the surface soil and weathered or disintegrated rock. Such rock as is included in this class is of a coarsely micaceous sandy nature, contains considerable yellow oxide and does not core well, the drill yielding small irregular fragments or else buttons. This rock is easily broken with the fingers and shows the results of exposure to water and the elements.

Windy Gap Dam Site.

At Windy Gap, shown on Plate C-VIII, the Fresno River leaves Fresno Flats through a gorge cut across a prominent topographic ridge—Crook Mountain-Potter Ridge—which locally is comprised of a black micaceous slate converted in part into mica schist, consisting of small crystals of the black mica biotite and quartz and representing the original sedimentary deposit into which the granite intruded and compressed into bands and altered into a hard crystalline rock mass. The bands strike across the stream bed and dip nearly vertical, north 30 degrees east 85 degrees. In some of the bands the schistocity is hardly discernible, but others present well developed planes along which the rock cleaves under weathering.

The schistocity and banding strike and dip the same, being caused by the same dynamic stresses. Later compression stresses, due to crustal movement, have developed two major joints in the mass, one dipping south 20 degrees west 35 degrees and the other dipping south

LOCATION OF

DIAMOND DRILL BORINGS

AT

BUCHANAN DAM SITE

ON

CHOWCHILLA RIVER

BORINGS MADE IN 1923

LOGS OF DIAMOND DRILL BORINGS AT BUCHANAN DAM SITE ON CHOWCHILLA RIVER, JANUARY, 1923

Depths, in feet	Classification	Material	Description of formations and cores
HOLE No. 101—			
0–6	1	Mica schist	About fifteen inches of two and one-half inch core was saved; 0 to 2 was probably sand; 2 to 6 top boulders.
6–40.5	1	Mica schist	Solid rock. Core shows an occasional close fitting seam. Quartz vein at 29.
40.5–76	1	Mica schist	Solid rock. Occasional close fitting seams. At 54 feet a flow of water was struck. While the tools were in the hole and no water flowing into the hole from the drilling, underground water would continue to flow out the top. When the tools were removed it did not flow out the top, but while drilling hole No. 105, the water was lost at 54 feet and the water from 107 came out of 101. Hole No. 101 is lower than 107.
76–98	1	Mica schist	Solid rock. Occasional close fitting seam. Indications of copper were very pronounced near the bottom of hole. Core shows some copper stains.
HOLE No. 102—			
0–5		Sand and mica schist	No core saved.
5–10	1	Mica schist	Close fitting seam about every four inches. Very
10–40	1	Mica schist	close fitting seams occur about every eight inches. Core broken at 23 to 24 and more seamy. Hard rock.
40–51	1	Mica schist	Few close fitting seams. Hard rock. Core somewhat broken by blocking of drill.
HOLE No. 103—			
0–12	2	Mica schist	Core is very much broken up. Some of it coming out much like pebbles. Contains much mica, is of a darker color than the rest of the core in the hole and is seamy.
12–18	2	Mica schist	Five feet of core saved. Four feet of core saved. Slightly less broken than from 0 to 12, but about the same amount of mica and the same color.
18–43	1	Mica schist	Hard rock with a few close fitting seams.
43–51.5	1	Mica schist	Hard rock with a few close fitting seams.
HOLE No. 104—			
0–5			No core saved. Drillers report shows talc and schist. There is no talc here.
5–34	2	Mica schist	Of a light brown color, fine grained, with close fitting seams about every three inches. More broken and more seams near the top of section. Report shows seam at 23.5 feet. There is no indication of a seam in the box.
34–56	1	Mica schist	Light gray color. Hard with occasional close fitting seam. Some broken at 49 to 50.
56–64.5	1	Mica schist	Hard rock with a few close fitting seams.
HOLE No. 105—			
0–8	1	Mica schist	Two and one-half inch core. Three feet of core saved. Close fitting seams running parallel with hole.
12–42	1	Mica schist	Very few close fitting seams.
42–79	1	Mica schist	Very few close fitting seams. (Note.—Water was lost at 48 and came up out of hole 101 on north side of river. No indications in Box 2 of any seam at that elevation.)
79–115	1	Mica schist	Very few close fitting seams.
115–121.5	1	Mica schist	No seams.
HOLE No. 106—			
0–5	1	Mica schist	Two and one-half inch core. Some close fitting seams.
5–37	1	Mica schist	Hard rock with a few close fitting seams.
37–57	1	Mica schist	Hard rock with very few close fitting seams.
HOLE No. 107—			
0–14	2	Mica schist	Two feet of core saved. What core is saved is No. 2, very broken and seamy.
14–20	2	Mica schist	Contains much mica, is broken into about two-inch lengths, and is full of small seams. Dark brown color. Lost water at eighteen feet.
20–50	1	Mica schist	Some close fitting seams. Quartz seam at 30 and 42.
50–59	1	Mica schist	Some close fitting seams. Core is somewhat broken at bottom of hole, caused by lack of water pressure.

PLATE C–VIII

GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES

IN THE VICINITY OF

WINDY GAP DAM SITE

ON

FRESNO RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Mica-schist

70 degrees east 85 degrees at nearly right angles to the banding. These lines of weakness, shown in Plate C-VIII, allow the mass to break into blocks at the surface under weathering.

The same bands of rock outcrop continuously from the crest of one abutment, across the stream bed and up the opposing abutment. The joint planes are closed tight features over fresh stream bed exposures, and probably would refuse grout at relatively short distances below ground surface. On the abutments, weathering has loosened joint blocks from the mass and produced a soil cover which probably would require an average excavation of fifteen feet to reach sound rock. Rock reefs are continuous across the stream channel and an average of ten feet excavation below stream bed should be sufficient to provide a key way for a concrete structure or core wall for a rock fill or earthen structure, the site being entirely suited to either type.

FRIANT, FORT MILLER, AND TEMPERANCE FLAT DAM SITES ON SAN JOAQUIN RIVER

The San Joaquin River drains the west flank of the Sierra Nevada and enters the San Joaquin Valley at about its center. Above the valley plain the river has cut a wide stream trench through the foothill area for a distance of approximately ten miles to the town of Friant, upstream from which the erosive development of the stream trench has provided narrower canyons with steep side slopes topographically suited for dam site purposes. The lowest of these in point of elevation is the Friant dam site located about one mile above Friant in section 5, township 11 south, range 21 east. Another, the Fort Miller dam site, is located on about the north line of sections 34 and 35, township 10 south, range 21 east. The narrowest gorge and steepest cliff profile development on the lower river is found at the Temperance Flat dam site, which crosses the river at about the center of the north line of section 25, township 10 south, range 21 east.

The topographic development of the region investigated is the result of the Sierra Nevada uplift in mid-Tertiary time, with the river erosive activity or base leveling processes being of geologic recent time. Rocks of the Tertiary age have been cut through, with but small remnants now remaining, and the underlying geologically ancient basement complex formation, with its somewhat younger intrusions, forms the rock mass into which the stream is vigorously cutting and out of which the stream trench has been carved. The topographic development is entirely due to differential erosion on a crystalline rock mass consisting of material which varies in its resistance to erosion and weathering, rather than being controlled by geologic structure. Horizontal corrosion and weathering has attacked the lesser resistant rock masses in places, widening the stream trench and producing gentle side slopes, but at the dam sites selected, stream erosion has proceeded more rapidly than atmospheric erosion of a more or less resistant rock mass and there the topographic development ranges from narrow canyon to gorges with cliff profile.

General Geology of Region.

The foothill region downstream from Friant consists of horizontal or gently dipping beds of sandstone and clay-shale, exposed as the capping of Table Mountain, overlying granitic rock. These beds are probably identical with the Ione formation of Tertiary Age. The underlying rock, as exposed below Friant is a coarse textured grano-diorite consisting of quartz, feldspar and hornblende, with occasional dikes of true granite or granitic rock containing the mica biotite. Overlying this formation at Friant is a heavy deposit of river gravel and alluvium occupying the present stream trench and an old river terrace deposit somewhat higher in elevation than the stream bed.

The formations were studied in sufficient detail and over an area wide enough to allow determination of their relationship to each other. This relationship is shown on Plate C-IX which purports to be general as but little time was given to its preparation in the field. The Tertiary sediments lie as a capping over the granite north of Friant. The terrace gravels are not distinguished from the present stream deposition, except by their topographic position.

The rocks of the basement complex, or "Bed Rock" series of Pre-Jurassic age, so designated by the publications of the U. S. Geological Survey, vary in origin and mineral constituents, but most have undergone change due to dynamic and/or contact metamorphism. Dynamic metamorphism, due to the intense distortion and pressure suffered by the rock formations during the great early (Jurassic) granitic intrusions, has, in this region, produced schists. The schistose structure strikes northwest-southeast across the region and the mineral constituents of the schists change in bands or zones from west to east. The predominant bands consist of mica schist, with quartz schist bands included, and talc schist near the contact. The basin above the schist area is made up largely of coarse textured granitic rocks containing dikes of fine-grained grano-diorite, alaskite, hornblende rock, and a basic rock consisting principally of magnetite. In this basin is a deposit of subaerial tuff consisting of extremely uniform and finely divided volcanic glass known commercially as pumicite. This deposit lies between 500 and 580 feet elevation and overlies disintegrated granite. There are also river terrace deposits overlying the granite.

It is possible that in this region granitic rocks were intruded at two different periods, the earlier intrusion being the coarse textured granite of the foothills and Fort Miller basin and the later intrusion being the fine textured grano-diorite of the Temperance Flat gorge; or the grano-diorite may be contemporaneous with the granite intrusion, and being closer textured was more resistant to weathering and more recently attacked by the stream through piracy of the upper San Joaquin by the Fine Gold Creek drainage. The latter rock is distinguished by a fresh and sound appearance in contrast to the disintegration and aged weathering which characterizes the surface of the basin rock. The dike rocks of radically different character also are absent and the whole presents a formation resistant to erosion and weathering.

Geologic Structure.

No faults of consequence were observed nor are any known in the region. The overlying Tertiary strata lie nearly horizontal and indicate that the mountain range has been uplifted without distortion or compression in more recent times. The joint planes and shear zones

PLATE C–IX

GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
TEMPERANCE FLAT
FORT MILLER AND FRIANT DAM SITES
ON
SAN JOAQUIN RIVER

SCALE OF MILES

0 1 2

LEGEND

Alluvium and terrace gravels
Tertiary sediments
Volcanics
Close textured grano-diorite
Coarse textured granitic rocks
Metamorphic series-mica schist

originating during the period of granitic intrusion are healed by the deposition of quartz and other infiltration products. Therefore any faults or shear zones in the rock masses are Pre-Tertiary, long dead and thoroughly healed fractures.

The earth stresses, due to the Tertiary uplift, produced new jointing common to all Sierra Nevada rocks. The formations are broken by several systems of joint planes, which are structural features persisting to considerable depth below ground surface without displacement along or parting of the joint walls. At the surface, rock blocks of varying sizes have parted from the mass along the joint planes and weathering has attacked certain of the joint walls, causing them to allow water penetration and effect some disintegration of the rock. The effect of this will be taken up in consideration of the detailed geology at each dam site.

Detailed Geology—Friant Dam Site.

The Friant dam site, occupies an area of complex metamorphic rocks which has been given the general name of mica schist. This rock contains several facies of granitic rocks in which intense crustal movement, with its accompanying pressures, have altered the original formations into gneisses and schists, accompanied by an increase in crystallization and hardness with the change in texture. The schistose rocks are those which predominate in mica, the brown muscovite being present in fairly large thin sheet crystals in some faces, with very little or without primary quartz, and with smaller crystals of the black biotite and quartz in others. The gneissoid rock might be termed a quartz schist, as large crystals of primary quartz predominate over the mica. Interspersed with the schist are rock bands in which the schistosity is hardly discernible and the rock is massive and close textured. These variations in rock character "band" the formation through variation in rock texture and mineral constituents, but, as all facies are perfectly crystalline, the mass is a strong fabric of interlocking crystals without any apparent texture weaknesses.

In the main the banding and schistosity strikes northwest-southeast and dips 50 to 60 degrees from the horizontal upstream, but the compressive forces which caused its development were such as to produce locally tortuous or contorted planes, which resemble shear zones and vary in strike to east and west and in dip to vertical and downstream.

The angle of dip of the planes of schistosity is important in relation to the strength of the rock as they are lines of cleavage along which the rock parts. The compressive strength of the rock varies from about 12,500 pounds per square inch, with the load applied at right angles to the planes, to about 3500 pounds per square inch when applied at an angle of 45 degrees to the planes. As the planes dip generally upstream and the resultant of the weight of the dam structure and the arch thrust components is inclined and dips downstream the rock mass will present its most effectual resistance to the combined stresses.

The rock is somewhat jointed with the most persistent jointing striking across the planes of schistosity and dipping southwesterly about 40 degrees from the horizontal. Shear zones and spaces caused by the parting of the rock under the original compression are entirely healed with secondary quartz filling, and no open fissures should persist beyond shallow depth. The net work of joints encountered in the cores is probably the result of the Tertiary uplift as they pass through quartz veins in the schist. The cores frequently have broken along these joint planes and most of the joints show water stain, but few are so open that water may circulate and, as the rock is stable and insoluble, there are none so enlarged through the action of percolating water to cause serious leakage from a reservoir.

On the whole the rock is one that resists erosion and weathering to a much greater extent than the granite adjoining it. It has long been exposed to the same agencies, yet sound rock is found at the surface in the stream bed and at moderate depths below the side slope surface. No extensive topographic draws, which would be evidence of zones of rock weakness have been developed on the slopes.

The rock at stream level is fresh and water-worn with the development of small potholes. The jointing exposed is irregular and not continuous and there has been no parting or weathering along the joints in the fresh rock. In some bands of rock along the fresh exposures of the stream bottom and in the cores examined, the schistosity is hardly discernible and the whole is shown to be a sound crystalline mass. The character of the bed rock in the stream bed is massive, regardless of the texture differences. This massive rock contains some few joints which, in the cores, are stained to depths of 25 feet below stream bed, but, as the stain could very readily have been produced by capillary moisture, it is believed the joints are of no consequence in allowing uplift effect on a dam or leakage under it and probably would refuse grout. These observations, however, in no way obviate the necessity for drilling and testing through water pressure or pressure grouting the joint planes in the foundation rock and up the abutments as part of the construction program.

The results of the core analyses, with detailed descriptions of physical characteristics of the cored rock, are given on subsequent pages. In connection with this analysis a prediction is made as to the depth of stipping necessary and the depth to which joints, which will take grout, persist. The estimated limit of stipping is shown graphically upon Plate C-X, "Location of Diamond Drill Borings and Test Pits at Friant Dam Site."

The bed rock forming the abutments on both sides of the river is the same, but the extent of soil and alluvial covering varies. The mantle of soil, consisting of disintegrated rock fragments imbedded in clay soil, which is the product of the decomposition of the rock, is relatively thin, ranging from one foot to three feet in the test pits examined. Underlying the soil cover, as revealed by the drill cores and pits, is disintegrated or partially broken down rock, which at depths of eight to twelve feet below ground surface merge with sound rock containing joints the walls of which have become somewhat disintegrated and which affect the soundness of the mass. The sound rock should be found along the limit of excavation indicated, and would require an average stripping of about 25 feet measured at right angles to the slope on the south abutment.

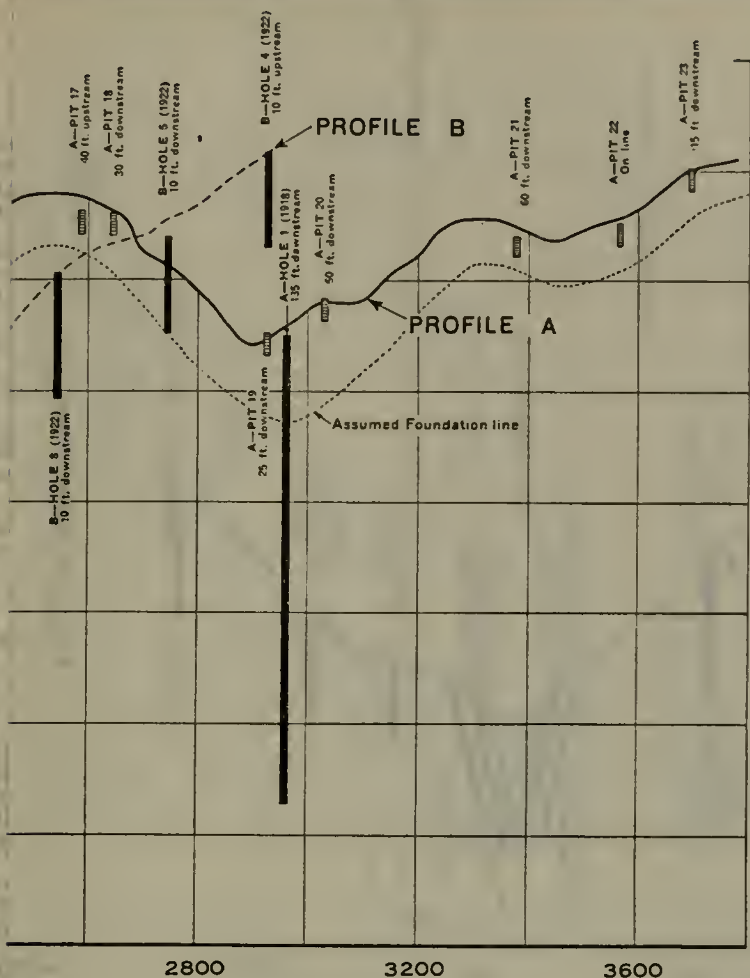
The north abutment contains an old stream terrace which represents the stream trench at a time its surface was 50 to 75 feet higher than the present stream bed. The carving out of this trench channel should be similar in contour to the present trench and as the drill holes were not closely enough spaced to definitely determine the contour it has been approximated in order to estimate the depth of stripping. Erosion had carried the gravels from the old channel down over the slope to the present stream bed. They are exposed in place to a depth of seventeen feet in Test Pit 3 and the core record of Hole 17 nearby, ten feet deep in Hole 19, seventeen feet deep in Hole 18, and but ten feet deep in Hole 20. All the pits from 2 to 7 show terrace gravels in place or as a wash soil covering over the slope.

The core of Hole 18 shows a depth of 54 feet before sound rock is reached, that of Hole 19 some disintegration of joint walls at 41 feet, and that of Hole 20 some disintegration of joint walls at 54 feet. It may be that stripping to a depth of 40 to 50 feet would be necessary over that portion of the north abutment occupied by the old terrace and it would be well to allow for an average depth of 40 feet stripping requirement over the entire north abutment in the estimate of cost. It is probable, however, that upon shallower stripping and the drilling and testing of joints showing some disintegration, grout would serve to prepare and provide a sound rock mass for the abutment.

The character of the bed rock is such as to be entirely satisfactory as foundation for a concrete arch or gravity type structure the full height of the proposed dam. The site provides a spillway location at the crest of the south abutment which would discharge the water down a topographic draw developed in the schist formation and into the stream about a half mile below the dam site. This schist formation is as resistant, below the soil cover and disintegrated zone, as the rock exposed at stream level. No exploration has been made as to depth to sound rock above Pit 25 at 600 feet elevation. Hole 25 showed sound mica schist at 30 to 40 feet below ground surface at a topographic saddle.

The stream bed and terrace gravels are now being worked commercially at Friant and would provide a nearby source of construction materials.

The following characteristics of rock and formations in open test pits, excavated during August and September, 1924, were compiled from records furnished by Harry Barnes, Chief Engineer, Madera Irrigation District, and from personal examination in March, 1930.



LOCATION OF

DIAMOND DRILL BORINGS

AND

TEST PITS

AT

FRIANT DAM SITE

ON

SAN JOAQUIN RIVER

BORINGS MADE IN 1918 AND 1922

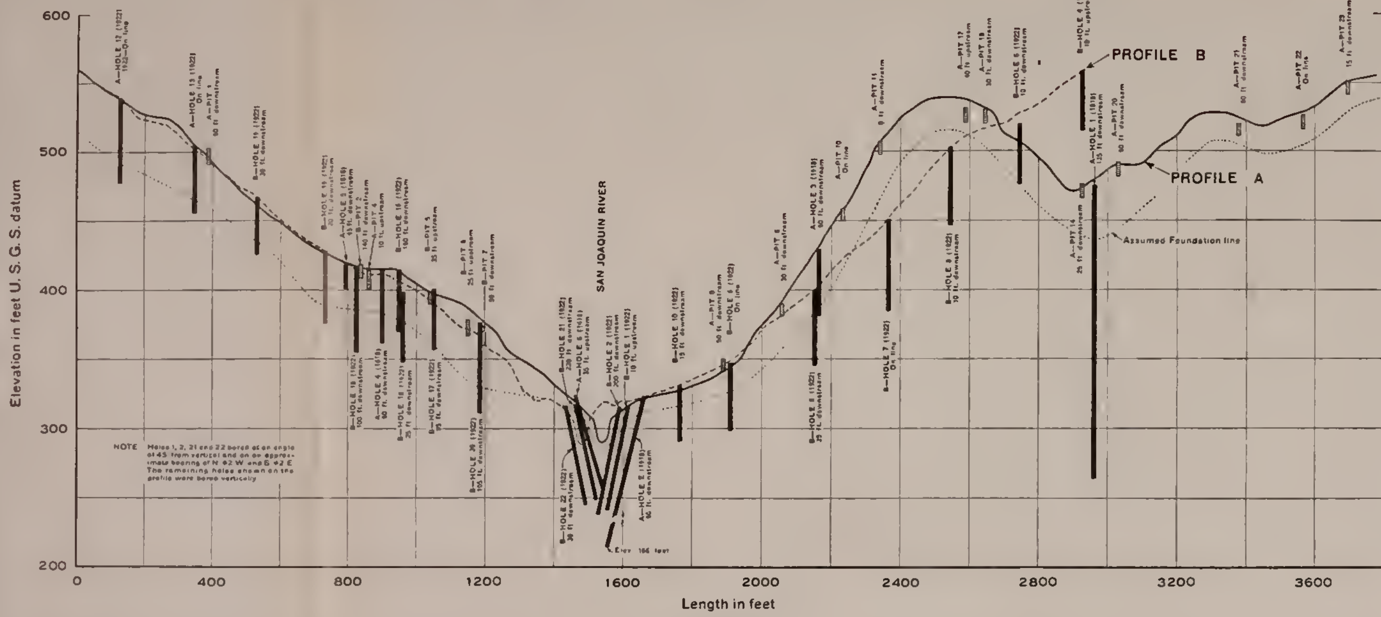
than the present stream bed. The carving out of this trench channel should be similar in contour to the present trench and as the drill holes were not closely enough spaced to definitely determine the contour it has been approximated in order to estimate the depth of stripping. Erosion had carried the gravels from the old channel down over the slope to the present stream bed. They are exposed in place to a depth of seventeen feet in Test Pit 3 and the core record of Hole 17 nearby, ten feet deep in Hole 19, seventeen feet deep in Hole 18, and but ten feet deep in Hole 20. All the pits from 2 to 7 show terrace gravels in place or as a wash soil covering over the slope.

The core of Hole 18 shows a depth of 54 feet before sound rock is reached, that of Hole 19 some disintegration of joint walls at 41 feet, and that of Hole 20 some disintegration of joint walls at 54 feet. It may be that stripping to a depth of 40 to 50 feet would be necessary over that portion of the north abutment occupied by the old terrace and it would be well to allow for an average depth of 40 feet stripping requirement over the entire north abutment in the estimate of cost. It is probable, however, that upon shallower stripping and the drilling and testing of joints showing some disintegration, grout would serve to prepare and provide a sound rock mass for the abutment.

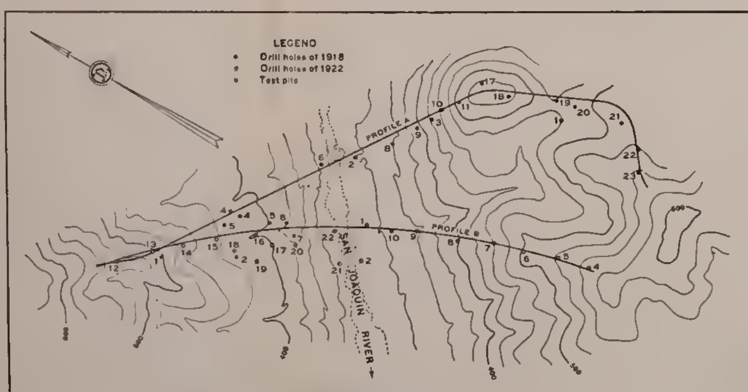
The character of the bed rock is such as to be entirely satisfactory as foundation for a concrete arch or gravity type structure the full height of the proposed dam. The site provides a spillway location at the crest of the south abutment which would discharge the water down a topographic draw developed in the schist formation and into the stream about a half mile below the dam site. This schist formation is as resistant, below the soil cover and disintegrated zone, as the rock exposed at stream level. No exploration has been made as to depth to sound rock above Pit 25 at 600 feet elevation. Hole 25 showed sound mica schist at 30 to 40 feet below ground surface at a topographic saddle.

The stream bed and terrace gravels are now being worked commercially at Friant and would provide a nearby source of construction materials.

The following characteristics of rock and formations in open test pits, excavated during August and September, 1924, were compiled from records furnished by Harry Barnes, Chief Engineer, Madera Irrigation District, and from personal examination in March, 1930.



PROFILES A AND B
LOOKING UPSTREAM



PLAN OF DRILL HOLES AND TEST PITS
FEET
0 400 800

LOCATION OF
DIAMOND DRILL BORINGS
AND
TEST PITS
AT
FRIANT DAM SITE
ON
SAN JOAQUIN RIVER
BORINGS MADE IN 1918 AND 1922

80997

TEST PITS—FRIANT DAM SITE

Pit No. 1, located by drill hole No. 13, elevation 505 more or less. Depth three feet, all hand work. One foot sandy loam soil, two feet of mixed gray and brown rock. Brown stain occurs irregularly throughout. No regular seams. Very micaceous, schistose texture, rock decomposition.

Pit No. 2, located by drill hole No. 18, elevation 415, on lower dam site. Depth 25 feet more or less, all hand work, through clay and terrace gravels to bottom. Landed in brownish stained coarse-textured disintegrated rock.

Pit No. 3, located by drill hole No. 17, elevation 400 on lower dam site. Depth 25 feet, more or less, all hand work. Ten feet of soil merging into light colored silty hardpan. Landed on brown and grayish rock of irregular occurrence.

Pit No. 4, located at old drill hole No. 4, elevation 418 more or less. Hole shot; ten feet, more or less, deep. Six feet of sandy clay loam, then gray rock, micaceous, schistose texture. Close irregular seams throughout carrying brown stain.

Pit No. 5, located at elevation 397 more or less, north of river. Hole shot; seven feet more or less deep. Three feet sandy clay loam. Four feet brown and gray mixed schistose. Laminated, micaceous, coarse granular structure, almost decomposed.

Pit No. 6, located at elevation 388 more or less, north of river. Hole shot; eight feet deep. Three feet sandy clay loam, one foot clay hardpan, two feet dry packed silt, two feet gray rock. Coarse schistose texture, somewhat micaceous with laminations. Close irregular seams carrying brown stain. Disintegrated.

Pit No. 7, located at elevation 374 more or less, north of river. Hole shot; seven feet more or less deep. One foot sandy loam; two feet water washed gravel, sizes up to four inches, then six inches of stratified pure clay and three and one-half feet of gray and brownish gray micaceous crystalline rock with irregular seams and with brown stain irregular throughout. Disintegrated.

Pit No. 8, located south of river, elevation 362 more or less. Hole shot; eight feet deep. Six inches of sandy loam. Rock grayish, stained with brown irregularly to eight feet. Irregular structure, seamy micaceous, schistose texture.

Pit No. 9, located south of river, elevation 418 more or less. Hole shot; eight feet, more or less, deep. Six inches of sandy loam. Rock gray, stained with brown for two feet, micaceous from three feet to eight feet. Brown stain in seams only, fine schistose texture.

Pit No. 10, located south of river, elevation 454. Hole shot; eight feet, more or less, deep. Twelve inches of sandy loam. Rock grayish, coarse schistose texture, very micaceous, grades to fine schistose texture. Irregular close tight seams; brown stain in seams, but occurring irregularly.

Pit No. 11, located at elevation 512 more or less. Hole shot; eight feet, more or less, deep. Rock similar to that of Pit No. 10, but coarser and easier to break.

Pit No. 12, located by drill hole No. 9, south of river. Hand work, eight feet more or less. One foot sandy clay loam, balance coarse grained decomposed quartz schist stained in irregular seams.

Pit No. 13, located south of river, elevation 391 more or less. Thirteen feet deep, hand work. Three feet sandy clay loam, ten feet grayish stained rock, irregular and very similar to Test Pit No. 8. Brown stain about two and one-half feet below this stain on seams.

Pit No. 14, located south of river, elevation 456 more or less, seven feet deep, hand work. Three feet soil and decomposed rock, three feet rather disintegrated rock with seams of decomposed rock and soil. Brownish stained rock, slab like structure at bottom. Bottom rock of decomposed fine grained schistose structure.

Pit No. 15, located south of river, elevation 504 more or less, by drill hole No. 4. Hand work, eight feet deep. Twelve inch soil; gray micaceous rock, much better than Test Pit No. 14, interspersed with brown irregular rock, with admixture of quartz, etc. Close seams carrying brown stains.

Pit No. 16, located south of river, elevation 544 more or less. Very micaceous, brownish, schistose rock, stained throughout, tight seams on schist structure, laminated, but fine texture.

LOGS OF DIAMOND DRILL BORINGS AT FRIANT DAM SITE, 1918

Location of Drill Holes Shown on Plate C-X

Hole	Direction	Depths in feet	Description of formations and cores
HOLE 1	Vertical	0– 8	Surface dirt and boulders.
		8– 11	Dirt and decomposed rock; landed casing at eleven feet.
		11– 20	Soft schist.
		20– 30	Schist, getting harder, micaceous.
		30– 50	Schist, less mica, nearly full core.
		50–109	Schist, practically full core.
HOLE 2	45° under river	0– 10	Sand, clay and boulders.
		10– 14	Schist, full core.
		14– 17	Schist; hole cased 5–10; landed.
		17– 92	Schist, full core.
		92– 93	Soft and lost water.
		93–105	Schist; cemented hole to hold water.
		105–141	Schist with quartz admixture.
		141–221	Schist and quartz schist.
HOLE 3	Vertical	0– 6	Decomposed schist, too soft to core.
		6– 17	Schist, too soft to core; landed casing.
		17– 38	Soft schist; eight foot core with double core barrel.
		38– 50	Schist, full core.
HOLE 4	Vertical	0– 10	Surface dirt and boulders; casing.
		10– 24	Clay and decomposed schist.
		24– 26	Soft and schist.
		26– 63	Schist and full core.
HOLE 5	Vertical	0– 10	Surface dirt and boulders.
		10– 17	Soft schist, micaceous.
		17– 18	Schist.
HOLE 6	40° under river	0– 10	Schist.
		10–112	Schist, full core.

Summary of Holes Drilled

Hole	Depths	Shifts	Footage per shift, actual drilling time
1	209	18	11.6
2	221	23	9.6
3	50	5	10.0
4	63	5	12.6
5	18	1	18.0
6	112	11	10.2
Totals	673	63	10.7 weighted mean

The above data compiled from log notes on file in office of secretary of Madera Irrigation District, by Harry Barnes, Chief Engineer.

Laboratory Certificate

SMITH-EMERY COMPANY
Chemical Engineers and Chemists
Los Angeles

April 19, 1923.

Laboratory No. 47253-6-7-8

Sample—Rock Cores

Received—4/5/1923

Marked (See below)

Submitted by—Madera Irrigation District, c/o Quinton, Code and Hill, Hollingsworth Building, Los Angeles, California

COMPRESSION TESTS

	Dimensions, in inches	Area in square inches	Maximum load, in pounds	Crushing strength, pounds per square inch
HOLE No. 3— 4 feet deep	1.13 diameter x 1 1/8	1.00	1,550	1,550
HOLE No. 7	1.17 diameter x 1 3/16	1.08	2,130	1,970
HOLE No. 11— 7 feet deep	1.08 diameter x 1 1/8	0.92	3,990	4,340
HOLE No. 14— 111.2 feet deep	1.78 diameter x 1 3/4	2.49	9,100	3,640

Respectfully submitted,

SMITH-EMERY CO.
Inspecting and Testing Engineers

Smith-Emery Co.
Seal

LOGS OF DIAMOND DRILL BORINGS AT FRIANT DAM SITE, 1922

Location of Drill Holes Shown on Plate C-X

Depth in feet	Material	Description of formations and cores
HOLE No. 1—		
0–5	Mica schist	The core was two and one-half inches and does not appear in the box.
5–11	Mica schist	From 6 to 9 seamy material, some quartz filling. One seam about 8.5 shows material much ground up, but portions are hard.
11–21	Mica schist	Water stained. Hard rock core in four-inch to one-foot six-inch lengths broken by blocking of drill.
21–26	Mica schist	Joints some water stained.
26–31	Mica schist	Hard rock only broken near 26-foot level by blocking of drill.
31–38	Mica schist	Hard rock only broken by the twist in the drill when blocking.
38–70	Mica schist	Hard rock, good cores only broken at the blocking points.
70–81	Mica schist	Hard rock and good cores.
81–86	Mica schist	At 83 feet the drillers lost the water in the hole. The core shows evidence of the drill vibration caused by striking diagonally the seams in the rock. A slight difference in hardness of the rock probably causes this vibration. The water came to the top of the hole when the 108 or 110-foot depth was reached. The core at 83 does not show any open joints or disintegration.
86–102	Mica schist	Hard rock showing some quartz veins.
102–112	Mica schist	Hard rock showing some quartz veins and some granitic formation.
HOLE No. 2—		
1–3	Mica schist	2½-inch core and was not put in box. Contained some seams, water stained.
3–7	Mica schist	Seam at 4 and 5. At 4 feet rock rather broken but broken portions are hard. No disintegration.
7–25^{5}	Mica schist	Continuous core but broken by drill into about three-inch pieces. Small seam was found at 17½.
25^{5}–37	Mica schist	Water was lost at 25½ where a small seam was found. Continuous core but broken into about three-inch pieces by drill.
37–58	Mica schist	Hard fine mica schist with no seams.
58–70	Mica schist	Hard fine mica schist with some quartz. No open seams. Joints clean and tight.
70–90	Mica schist	Hard fine mica schist with no seams.
90–92	Mica schist	Broken by drill.
92–102	Mica schist	Hard mica schist, schistosity hardly discernible.
102–108^{9}		Hard mica schist.
HOLE No. 3—		
0–4	Top soil	Material other than earth too soft to core.
4–9^{9}	Disintegrated schist	Much broken up with small seams and does not core well. Maximum length of portions of core about two inches.
9^{9}–19^{9}	Mica schist	Broken core, seamy with clay seams at 11 and 15 and some talc at 19.
19^{9}–32	Mica schist	Disintegrated. Many small seams. Core comes out in about two-inch and three-inch pieces, although some better pieces at 22 and 29.
32–43^{4}	Mica schist	Some few small seams following the cleavage. Water stained. Some disintegration on seam at 30 feet.
HOLE No. 4—		
0–6^{4}	Top soil	Broken sandstone too soft to core.
6^{4}–17^{4}	Mica schist	Seamy mica schist, one-inch to two-inch pieces, water stained.
17^{4}–32	Mica schist	Seamy mica schist, two-inch to three-inch pieces.
32–43	Mica schist	Hard, but some close-fitting joints. Water stained, but no disintegration.
HOLE No. 5—		
0–7	Top soil	Too soft to core.
7–22	Mica schist	Broken seamy soft rock. Some large joint openings, water stained and disintegrated. Core comes out in about average of one-inch length. Lost water at 21 feet.
22–30	Mica schist	Close-fitting jointed rock about two joints per foot. Water stained.
30–43^{8}	Mica schist	One close-fitting joint at 35 feet, water stained. Core broken by drill.
HOLE No. 6—		
0–9^{5}	Hardpan	Too soft to core. Hardpan argillaced 10-12 feet some clay and sand streaks.
9^{5}–29^{5}	Mica schist	Soft seamy formation mostly too soft to core. Disintegrated and water stained.
29^{5}–35	Mica schist	Seamy schist.
35–37	Mica schist	Compact rock.
37–50	Mica schist	Rock is hard, but has joints about every three to four inches.
50–55^{9}	Mica schist	Hard schist with occasional close-fitting joint, water stained.

LOGS OF DIAMOND DRILL BORINGS AT FRIANT DAM SITE, 1922—Continued

Location of Drill Holes Shown on Plate C-X

Depth in feet	Material	Description of formations and cores
HOLE No. 7—		
$0-9^{8}$	Top soil	Too soft to core, chiefly washes away with the water. No core saved.
$9^{8}-12$	Disintegrated rock	Too soft to core. Small portions saved.
12–30	Mica schist	Soft rock containing a great deal of mica and full of seams, one about every two or three inches. Disintegrated.
30–43	Mica schist	Seams are close fitting, tight, and no disintegration.
43–46	Mica schist	About three joints in mica schist. Water stained.
46–60	Mica schist	Close-fitting joints about every two inches. Water stained.
$60-66^{3}$	Mica schist	Hard rock with very close-fitting joints one about every half foot.
HOLE No. 8—		
$0-10^{3}$	Top soil	Too soft to core and no core saved.
$10^{3}-14^{3}$	Mica schist	Small seams about every two inches. Disintegrated.
$14^{3}-23$	Mica schist	Small close-fitting joints about one every two or three inches. Water stained, but no disintegration.
$23-53^{5}$	Mica schist	Small close-fitting joints about one every two or three inches.
HOLE No. 9—		
$0-12^{8}$	Top soil	Driller's report shows ground too soft to core above 12^{8}. The beginning of the core at 12^{8} shows rock above that elevation. No other information is available above that elevation. Ground surface shows earth and broken rock.
$12^{8}-20$	Mica schist	Close-fitting seams about every three inches. Water stained.
20–25	Mica schist	Joints about every two inches. No disintegration.
25–26	Quartz	Broken by blocking drill.
26–28	Mica schist	No seams.
28–30	Mica schist	Hard rock.
30–34	Mica schist	Close-fitting joints.
34–40	Mica schist and quartz	Mica schist portion is soft and the quartz is hard.
$40-48^{7}$	Mica schist	Hard rock with few close fitting joints. While joints show water stain, it is probable they would refuse grout.
HOLE No. 10—		
$0-8^{3}$	Top soil	Report shows no core from 0 to 5 feet and from 5 to 8^{3} decomposed ground. No core is shown in box above 8^{3}.
$8^{3}-14^{5}$	Mica schist	Disintegrated rock. Seams 14 feet. Lost water. Other small, close-fitting seams.
$14^{5}-17$	Mica schist	Small close-fitting joints.
17–36	Mica schist	No seams, close-fitting joints.
36–38	Talc rock	No seams, close-fitting joints.
$38-39^{3}$	Mica schist	No seams, close-fitting joints.
HOLE No. 11—		
0–12	Clay and hardpan	Too soft to core.
12–18	Mica schist	No wide seams. Joints water stained.
19–29	Mica schist	Small close-fitting joints.
$29-41^{3}$	Mica schist	Small close-fitting joints about every foot, sound rock.
HOLE No. 12—		
0–10	Top soil	No material saved.
10–19	Disintegrated	Very soft and decomposed schistose formation, but very granular.
19–47	Disintegrated schist	Decomposed and broken down. Six-inch clay seam at 40 feet.
47–50	Mica schist	Some close fitting joints. Water stained.
50–59	Mica schist	Hard rock with few close fitting joints. Some water stained.
59–62	Mica schist	Close-fitting joints.
HOLE No. 13—		
0–18	Top soil	Too soft to core.
18–26	Mica schist	Very seamy and broken. Disintegrated.
26–27	Mica schist	No seams.
27–39	Mica schist	Close-fitting joints. Water stained.
$39-49^{1}$	Mica schist	Close-fitting joints about one per foot.
HOLE No. 14—		
$0-10^{5}$	Top soil	Decomposed sandy rock and clay.
$10^{5}-14$	Mica schist	Decomposed and seamy.
14–18	Mica schist	Seams about every one-half foot. Clay seam at 18 feet. Disintegrated rock.
18–25	Mica schist	Decomposed seamy rock.
25–30	Mica schist	Close-fitting joint, one about every foot. Water stained.
30–41	Mica schist	Close-fitting joint, one about every foot.
HOLE No. 15—		
0–10	Top soil	Too soft to core and no core saved.
10–16	Disintegrated	Seams every four inches.
16–27	Mica schist	Mica schist, very seamy.
27–35	Mica schist	Many close-fitting joints. Water stained.
35–39	Mica schist	Close-fitting joints. Water stained.
39–45	Mica schist	Close-fitting joints, some water stained.
45-47	Mica schist	Sound rock.
47–52	Mica schist	Solid rock.

LOGS OF DIAMOND DRILL BORINGS AT FRIANT DAM SITE, 1922—Continued

Depth in feet	Material	Description of formations and cores
HOLE No. 16—		
0–43	Top soil	Sand, clay and decomposed schist, too soft to core much.
43–50	Mica schist	No seams. Close-fitting joints not water stained. Total of nine feet of core from this hole. Apparently in terrace gravel pocket.
HOLE No. 17—		
0–17	Top soil	Sand, clay and gravel; casing 17 feet.
17–21	Mica schist	Seams, partially disintegrated rock.
21–30	Mica schist	Close-fitting seams. Lost water at 26 feet. Two additional joints showing some water, weathering and disintegrating.
30–44 [4]	Mica schist	Close-fitting joints, some water stained.
HOLE No. 18—		
0–17	Top soil	Decomposed schist, sand and clay and terrace gravel formation.
17–21		
21–24 [5]		
24 [5]–29	Mica schist	Too soft to core. Disintegrated.
29–51	Mica schist	Too soft to core. Lost water 44 feet.
51–53 [6]	Talc and clay	Report shows talc and clay. No core shown.
53 [6]–59 [1]	Mica schist	Clean joint walls.
HOLE No. 19—		
0–5	Top soil	No core saved.
5–9	River wash	No core saved. Gravel, debris, etc.
9–16	Mica schist	Close-fitting seams showing some water stain.
16–20		Report shows clay showing some water stain, but no disintegration.
20–35 [6]	Mica schist	Close-fitting joints showing some water stain, but no disintegration. (NOTE.—Lost water at 35 feet).
35–44 [6]	Mica schist	Seam at 39 and 41. Disintegrated.
HOLE No. 20—		
0–10	Top soil	Too soft to core.
10–35	Mica schist	Too seamy to core.
34–44	Mica schist	Seams about every three inches showing disintegration and water stains.
44–46	Quartz schist	
46–55	Mica schist	One small seam at 54 feet. Close-fitting joints.
HOLE No. 21—		
0–7	Mica schist	One small seam at about three and seven with three close-fitting seams between. Water stained.
7–13 [6]	Mica schist	No seams.
13 [6]–16 [6]		Seam at 14 and 15.5. Water stained.
16 [6]–33	Mica schist	Hard rock with no seams.
33–36	Mica schist	Two close-fitting joints, water stained.
36–66	Mica schist	Mica schist streaked with quartz. Very hard, with an occasional close-fitting joint.
66–81	Mica schist	Mica schist streaked with some quartz. One small close-fitting seam at 77.
81–98	Mica schist	Hard, with only an occasional close-fitting joint.
HOLE No. 22—		
0–3	Mica schist	Three close-fitting joints. Water stained.
3–22	Mica schist	Close-fitting joints at 3, 7, 8, 9, 17, 19.5, 19.7, 20.8. Somewhat larger seam at 21.8. Firm, sound rock.
22–32	Mica schist	Close-fitting joints at 22.5 and 23.2. Rock is streaked with quartz.
32–38	Mica schist	Rock is mixed with quartz and jointed to break up, there being only about three feet of core saved. Probably some close-fitting joints between the quartz and mica schist. Schistosity is hardly discernible.
38–70	Mica schist	Close-fitting seams at 40, 42, 47.5, 48 and 64. (NOTE.—The drill report shows that water was lost at 68 feet. From 65 to 70 the core is continuous without a break and shows no seam.)
70–100 [2]	Mica schist	Solid rock of probably more a granite formation than a mica schist. No seams.

Laboratory Certificate

ABBOT A. HANKS, INC.

Lab. No 19911 to 19924, Incl. Date Sept, 25, 1924.

Sample—Rock cores

Received—9/23/24

Marked Diamond Drill Rock Cores Samples A to N, from Dam Site Near Friant

Compression Tests

Submitted by—San Joaquin River Water Storage District, Los Banos, California.

We wish to report the results of the compression tests of the rock samples, marked "A" to "N," inclusive, which you submitted to our laboratories.

The samples were received in the form of diamond drill cores and we were able to prepare one test piece from each sample, each specimen having the height equal to the diameter.

As the relation of the direction of the applied load to the plane of bedding, grain or cleavage in a rock has a direct effect on the compression test results, we have recorded this angle wherever it was apparent.

RESULTS OF INDIVIDUAL TESTS

Laboratory Number	Sample	Cylinder size		Area in square inches	Angle "C" in degrees	Compression strength	
		Height in inches	Diameter in inches			Maximum load in pounds	Pounds per square inch
19911	A	1.14	1.18	1.093	40	2,980	2,725
19912	B	1.10	1.14	1.020	5	3,710	3,635
19913	C	1.10	1.18	1.093	0	13,340	12,198
19914	D	1.10	1.18	1.093	20	9,690	8,861
19915	E	1.10	1.19	1.112	15	6,620	5,952
19916	F	1.12	1.20	1.131	20	9,620	8,506
19917	G	1.14	1.18	1.093	25	4,650	4,252
19918	H	1.16	1.16	1.056	30	3,010	2,848
19919	I	1.16	1.15	1.038	25	3,910	3,764
19920	J	0.98	1.20	1.131	30	4,750	4,200
19921	K	1.18	1.15	1.038	45	3,660	3,524
19922	L	1.10	1.16	1.056	35	5,790	5,479
19923	M	1.16	1.19	1.112	45	5,120	4,603
19924	N	1.18	1.19	1.112	45	3,900	3,506

REMARKS.—The test specimens were in cylinder form, the height and diameter of which is recorded. The slight variation in diameters of the cores is undoubtedly due to variations in character of rock.

The angle "C" is the angle between the vertical axis of the cylinder and the apparent plane of cleavage in the specimen.

We will be pleased to answer any further questions in connection with these tests and will store the samples for this purpose.

Respectfully submitted.

(Seal of Abbot A. Hanks, Inc.) R. E. NOBLE AND COMPANY

By Theo. P. Dresser, Jr.,
Chief Engineer

Detailed Geology—Fort Miller Dam Site.

About one-half mile upstream from the Friant dam site the contact between the metamorphic, or schist formation, and the granitic intrusion passes through the reservoir site. The contact is bordered by a series of weaker rocks in the metamorphic series and a coarse textured granite rock which has weathered down to form the wide basin bordering the stream trench. The coarse textured rock extends through the Fort Miller dam site to about the mouth of Fine Gold Creek. It contains many dike rocks of differing mineral constituents. The whole makes up a crystalline mass in which the crystal fabric has been broken down at the surface through the action of the weather and the penetration of water. This has resulted in a residuum of so-called rotten granite, from which the unstable minerals have been decomposed and removed, overlying a sound crystalline rock. The strength of the sound rock is unquestioned, but the depth to sound rock at the dam site is extremely uncertain and in the absence of subsurface pit or core drill exploration can only be inferred from certain evidences.

The "basin" on which the Fort Miller dam site lies is presumably an older surface than the Temperance Flat dam site and has been subjected to a long time weathering. The pumicite deposits, which are probably of Tertiary age, rest upon residuum from granitic rocks at about elevation 500. The slope of the stream is but eight feet per mile from the mouth of Fine Gold Creek to the Friant dam site and the stream bed elevation at Friant dam site is 310 feet. The base level for the drainage that formerly emptied through the basin area long has been achieved. There is no fresh bed rock exposed at the stream bed level and such rock as does outcrop is found to be considerably jointed, having disintegrated along joint planes. Where joints are close (a few inches to two feet) together, the rock has completely disintegrated between the joints and there is but little sound rock exposed in place.

Because of these conditions and experience had with similar rock exposed or drilled to depth below ground surface, it is estimated sound rock which could be used as foundation with reasonable grout preparation of weathered joint planes will lie, on the average, about 50 to 60 feet deep at right angles to the ground surface slope.

Joints through which water may circulate and which contain the stable products of decomposition—quartz sand—which make pressure grouting difficult may extend another 60 feet below rock line. On the whole the Fort Miller dam site is the least desirable from a geological standpoint of those examined on the San Joaquin River.

The upper abutments consist of the same coarse textured granite and have a fairly heavy soil cover, with but few outcrops of rock in place. Just above the dam site, granite outcrops appear near the crest of the ridge and the rock has a lighter soil cover. It is probable the lavas capping the ridge to the south, extended to the abutment ridge and were a protecting factor through which the topography has more recently developed, thus accounting for the freshness of the upper abutment rock. A spillway location is available in this rock at the crest of the north abutment of the dam site.

Detailed Geology—Temperance Flat Dam Site.

At the mouth of Fine Gold Creek the river emerges from a gorge cut through a close textured granitic rock—granodiorite. The fall of the river through the gorge and Temperance Flat averages about 20 feet to the mile, but for the first five miles above the flat the fall is 40 feet per mile. This development of a base level, taken in connection with the topographic development of Auberry Valley, suggests the pirating of the upper San Joaquin River by the Fine Gold drainage, with the geologic recent cutting of the gorge.

This active erosion and the fact that the rock is closer textured upstream from the mouth of Fine Gold Creek accounts for the apparent freshness of the exposed rock. The rock is a crystalline mass, being fairly uniform in texture and mineral constituents for a distance of 1000 feet upstream from the mouth of Fine Gold Creek. It is sound, stable and has great strength. In the mass it has resisted erosion so that a narrow gorge having a steep sloping cliff has been developed.

The formation is considerably jointed, with the main joint system striking across the stream and dipping downstream about 75 degrees from the horizontal and being intercepted by joint planes striking with the stream and dipping about 50 degrees toward the east. Two other minor joint systems intercept these at oblique angles and they, as well as other irregular joints, are accentuated at the surface, but have little importance in the mass. In fact, though the joints are structural defects in the rock mass, they are not to be considered as greatly weakening the mass nor detrimental to a structure founded thereon. The crustal movement which produced them did not cause any movement along the joints or parting of the joint walls. Though the movement long has been complete, there is no sign of infiltration products deposited on the wall rocks of joints opened by surface weathering.

The joint walls are sound and show no signs of disintegration at the surface. At the stream edge, in the freshly eroded rock, the joints were tightly closed and should be found closed at short distances below ground surface and incapable of transmitting water or water pressure below the stream bed or on the abutments.

At the dam site the lower section above stream bed has developed a narrow gorge with a smooth rock cliff profile along the joint plane paralleling the stream and dipping toward it from the left. Along the left abutment, parallel to the surface, a joint block has loosened and partially spalled off. Subsurface exploration is necessary to determine whether or not parting has occurred along parallel joints. The right abutment below the cliff line appears to be sound and necessary stripping could be limited to that required to remove loose joint blocks and key in a structure. The upper portion of both abutments consists of rock in place, with dislodged or loose joint blocks and a shallow soil covering spotting the steep slopes. The depth of rock over the stream channel should be but little in excess of the projection of the side slopes, with some limited pothole development.

The site is such that the geological and topographical conditions combine to make an excellent site and foundation for a concrete arch type structure. There is no natural spillway location so the spillway would necessarily be part of the structure and the overflow had over the same resistant rock that is exposed in the stream channel and which is not subject to rapid erosion.

PINE FLAT DAM SITE ON KINGS RIVER

Kings River emerges from the foothills about ten miles north of Reedley and for a distance of eight miles upstream from that point to Piedra passes down a comparatively wide stream trench.

The Pine Flat dam site lies about four miles upstream from Piedra in Section 2 of Township 13 South, Range 24 East. Above, through Pine Flat, and below to Avocado, stream erosion and weathering has widened the stream trench and produced gentle side slopes. At the dam site erosion has been confined to a canyon, slopes are precipitous and sound rock is in place close to the surface.

General Geology.

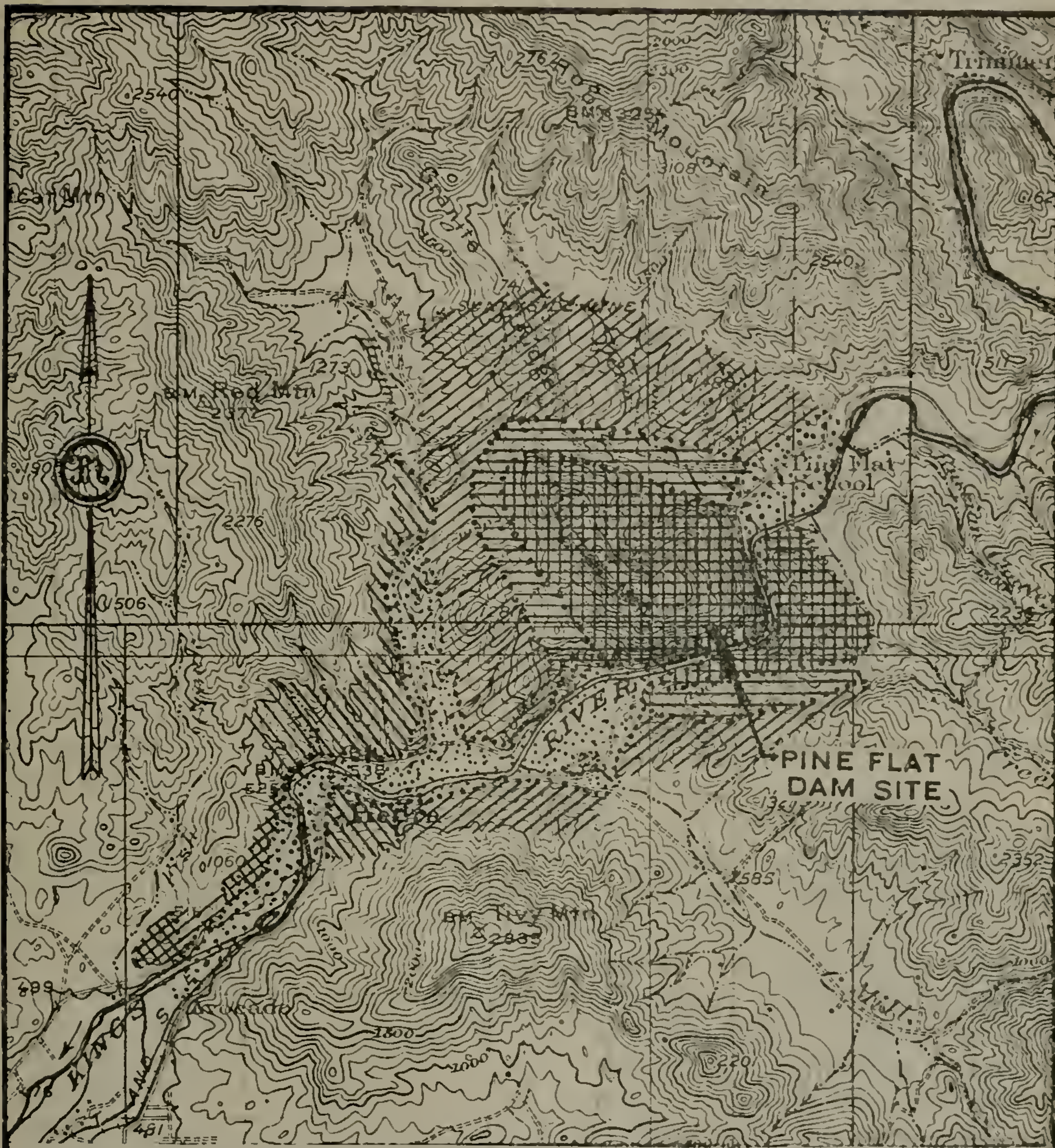
The relation of the topographic development to the geology of the region is shown on Plate C-XI. In common with the western flank of the Sierra Nevada, the rock formations here consist of a series of geologically ancient rock, now known as the basement complex metamorphics, in contact with igneous rock bodies whose intrusion into the mass are responsible for the metamorphism or change it has undergone. The original rocks have been recrystallized through the intense pressure accompanying the intrusion and their chemical constituents have undergone change through reaction with the gases under the heat from the molten magmas then at a great depth below the surface. Such action upstream from Avocado has produced a series of schists, slate and granitized rocks in which granitic dikes are found. Then follows a band of serpentized rock with true serpentine and its weathered product, magnesite, in limited zones, further altered along the contact with a larger granitic plug or dike from a plug. Upstream from the granitic rocks is found another zone of granitized rocks which becomes hornblendic, going from grano-diorite to diorite in a gradual mergence with a large body of extremely fine grained hornblendic metamorphic rock in which the dam site lies.

The schists and serpentine are rocks readily attacked by atmospheric weathering and stream erosion. The granite lying above is coarse textured and subject to weathering. The fine textured hornblendic rock, however, is dense and hard and thereby resistant to weathering and stream erosion, which accounts for the narrow canyon and steep slope development at the dam site.

Geologic Structure.

The region investigated, in common with the west flank of the Sierra Nevada, is one in which no geologically recent crustal disturbance has taken place. The intrusions of the granitic rock bodies, which caused great folding and faulting of the preexisting rock formations, took place in Jurassic time. Through the subsequent ages all fault and shear zones have become thoroughly healed by the deposition of infiltration products and, with the recrystallization of original rock masses due to metamorphism, the whole presents a structural unit unbroken by faults or zones of rock weakness. The stresses that caused the metamorphism were such as to band the formations. The banding generally strikes northwest-southeast and the rock bands change in chemical constituents and texture across the bands. The topography is the result of differential erosion of the mass, horizontal

PLATE C–XI



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
PINE FLAT DAM SITE
ON
KINGS RIVER

SCALE OF MILES
0 1 2 3 4

LEGEND

Alluvium	Schists
Granitic rocks	Granitized rocks
Serpentized rocks	Meta-diorite

corrosion attacking the less resistant rock bands to form draws tributary to the major stream and widening its trench, and the more resistant rock bands withstanding this attack with stream erosion developing gorge or canyon profiles.

The later Tertiary uplift of the region was accomplished without great distortion, but the compressive stresses which accompanied it produced several systems of joints which break the rock masses into relatively small blocks, though without displacement of the joint blocks or parting of the joint walls. That the jointing is a structural feature is attested to by the fact that the present topography has been developing since Tertiary time, and the present surface is hundreds or thousands of feet below the Tertiary surface. As the topography developed, rock blocks of various sizes parted from the mass along joint planes, gravitated to stream bed and were carried away. Weathering attacks the rock surfaces and joint walls, accomplishing decomposition and disintegration of the rock in place and allowing the penetration of water to carry on its work, chemically and mechanically, to effect a breakdown of the surface of the mass. These processes are surfacial in effect and the presence of joints beyond the depth of the reach of weathering, even though carrying some water stain, are not evidence of a weakened rock mass.

Detailed Geology—Pine Flat Dam Site.

The rock mass in which Kings River has entrenched itself at the Pine Flat dam site is a "greenstone," the chief rock-making member of which is hornblende. The latter is the result of metamorphism or alteration of the original crustal rock—probably diorite—due to intense pressure, heat and gases accompanying the granitic intrusion. The changes brought about through compressive forces have been such that the original rock cannot be readily recognized except that it must have been composed of basic minerals which, through recrystalization, have increased in hardness and compactness so that the result is a massive crystalline rock of great strength. At the dam site it is an extremely fine textured dark green rock consisting principally of minute crystals of hornblende and alkali feldspar. It has developed limited schistocity, due to the parallel arrangement of hornblende crystals, the foliations of which resemble shear zones. The whole mass is banded, as shown by the outcrops on the north abutment, with the bands dipping northeasterly about 40 degrees. This banding is an old structural feature and is not due to bedding of the rocks or changes in rock character, other than texture changes. The greater portion of the bands are comprised of fine grained massive rock which is extremely hard, fresh and strong. Under the hammer a greenish gray powder, which consists of minute grains of hornblende and feldspar, develops.

Along the center line of the dam site, between 850 and 1,000 feet elevation in the south abutment, the texture and character of the rock changes in a gradual mergence with rocks which have not suffered the same degree of change or have become granitized from the intrusion. The actual contact between the granitic intrusion and the older crustal rocks lies over the south abutment ridge and is marked by development of a topographic draw. The rock mass is weakened only at the contact, along which is found quartz veins carrying hornblende crystals, and between the contact and the massive rock, just described, occur granitic dikes, dikes of diorite and dikes of hornblende rock. The surface rock and the cores show the mergence to be a thoroughly knit crystalline fabric without any weakness due to heat, shrinkage and contact metamorphism, such as accompanies the line separating an igneous intrusion from the rocks into which it has intruded. Therefore, the whole presents a rock of great strength and hardness upon which to found a dam.

Jointing. The jointing, previously referred to as having originated during Tertiary time, while being a universal structural defect of the rock mass, is not to be considered as greatly reducing the strength of the whole or the safety of a structure founded upon it. The principal joints at the dam site consist of one striking at approximately right angles to the banding and dipping about 80 degrees, one approximately parallel with the banding and dipping northeasterly, and another intersecting these at an oblique angle and dipping about 50 degrees westerly. These joints are accentuated at the weathered surface and, though the course of the stream is not dictated by their presence, their topographic development along the south abutment is influenced by the jointing. Joint blocks have parted from the mass and gravitated out of place, allowing more ready attack of the weather. Hand samples picked from surface float, when struck with a hammer part in thin layers somewhat resembling irregular slaty cleavage along a multitude of irregular joints. In the sound rock these joints are hair lines which part under hammering, leaving smooth, clean surfaces.

In the cores examined (the analysis of which is appended to this report and the location of the holes and their inclination shown in Plate C-XII) some joints were noted below the stream bed, but the joint walls, being composed of hard, insoluble rock, were not disintegrated, nor did they show signs of water circulation. At depths greater than five feet below rock line the joints were closed and tight. Such crevices noted in drilling were quartz filled and the whole joint system probably would refuse grout at shallow depth when drilled and tested as part of the construction program. They in no way need be considered as means of effecting uplift on or leakage under a dam.

At the surface, the rock has parted along joint planes and has completely broken down to a clay soil carrying rock fragments for depths up to three feet and become partially disintegrated to depths of three to fifteen feet in addition. Below this depth are some joints along which water has circulated and caused some disintegration of the mass. These conditions, as revealed by the subsurface exploration, are spotted over the site. On the average, it should not be necessary to strip below fifteen feet. Some portions will require but five to eight feet, while limited areas, in topographic draws, will require as much as thirty feet. Most of the joints at those depths will be found tight, though carrying some water stain. Pressure grouting could be used effectively in closing all open joints up the abutments.

The character of the rock and the topographic development at the site is admirably suited to the construction of a concrete arch dam. The rocks making up the reservoir embankments are all stable, insoluble and incapable of passing water. A natural spillway is lacking, so the spill should be part of the dam structure, preferably at the north abutment, where the overflow would pass down the slope at right angles to the massive rock bands, which would resist erosion and require only a structure to retain it from working around to the toe of the dam.

The stream bed gravels and sand above and below the dam site provide a near-by source of construction material.

SUMMARY OF DATA RELATING TO DIAMOND DRILL EXPLORATIONS OF PINE FLAT DAM SITE, WITH CORE ANALYSIS

Hole No. 1—Elevation 554.8—Total depth 100 feet; core recovery 95 feet; broken to five foot joints clean and tight; some quartz filling.
Material—Massive amphibolite encountered three feet below surface. Lost two feet of core 46–60; one water stained joint; no disintegration.

Hole No. 2—Elevation 552.8—Total depth 100 feet; core recovery 93 feet; 0–5 feet cased; lost core 10–12 feet.
Material—Massive amphibolite encountered two feet below surface. Lost core 24–25 feet broken by quartz veins. Lost core 52–54 feet broken and creviced, no signs of water.

Hole No. 3—Elevation 563.2—Total depth 120.5 feet; core recovery 116.6 feet; 0–4 feet cased; lost 2 feet of core.
Material—Massive amphibolite encountered two feet below surface. Creviced at 17 feet, 18½ feet, 29 feet and 30 feet, but no sign of water; probably coarser less altered rock; 24–27 feet lost two feet of core, broken and creviced.

Hole No. 4—Elevation 562.2—Total depth 120.6 feet; core recovery 116.7 feet; no core to 7½ feet, jointed rock; some disintegration.
Material—Broken and considerably water stained joints first twelve feet and somwhat jointed to 27½ foot depth, remainder massive amphibolite. This hole required 27 feet of casing. Joints reported at 90, 96, 101 and 102½ feet; some slight water stain at 101 feet, but joint walls are stable rock; no disintegration.

Hole No. 5—Elevation 569.02—Total depth 33.8 feet; core recovery 29.9 feet; lost three feet of core 0–16 feet.
Material—Massive amphibolite two feet below surface; joints to 9–15 feet all healed closed features.

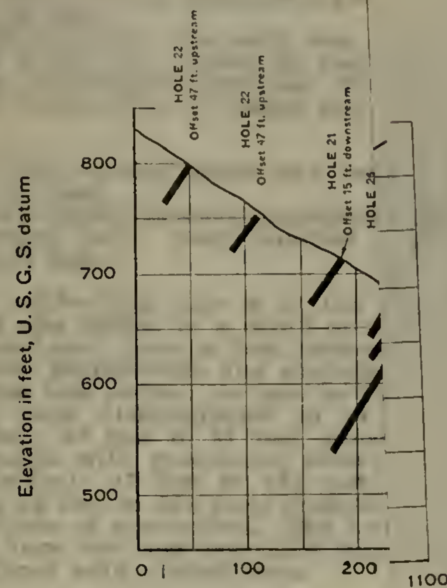
Hole No. 6—Elevation 573.4—Total depth 30.9 feet; two feet of soil at surface. Total core recovery sixteen and nine-tenths feet. Lost three feet of core 17–30 feet.
The upper fourteen feet of this hole was thoroughly broken by joints. Lost seven feet of core through which a casing was necessary. The rock below this point was hard amphibolite, but somewhat jointed, resulting in broken cores, but joints were clean, tight and probably would refuse grout.

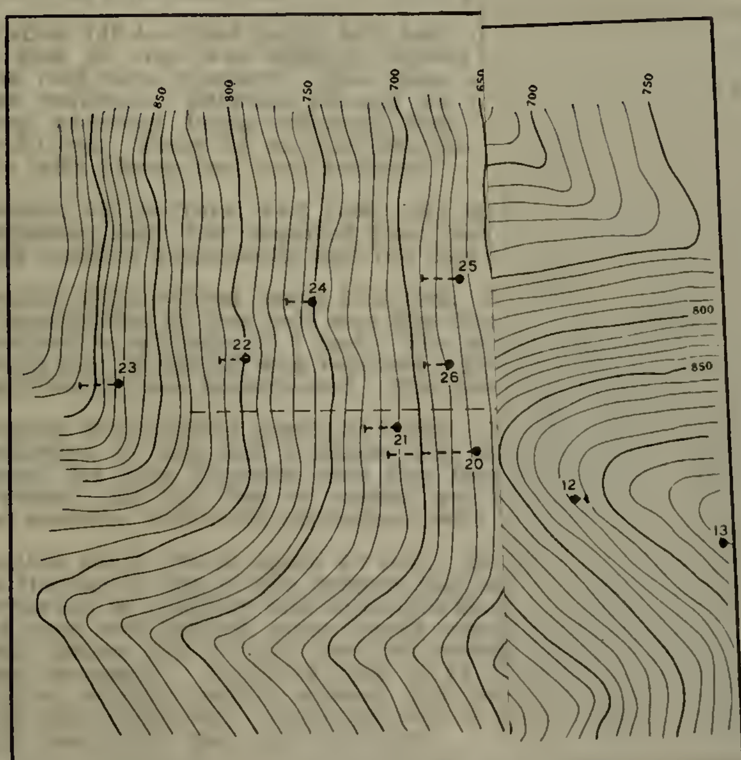
Hole No. 7—Elevation 596.1—Total depth 30.5 feet; core recovery 26 feet; lost first three feet jointed.
Material—Massive amphibolite below 5 feet.

Hole No. 8—Elevation 688.4—Total depth 29.9 feet; two feet clay and disintegrated rock at surface. Below this two feet of broken and creviced rock requiring, in all, four feet of casing.
From 4 to 14 feet, rock somewhat jointed and at depth 5 to 6 feet the water escaped. Below at depth 14 feet to 23 feet, seven feet of core recovered. Broken and jointed between depths 16 to 17 feet. No water stains, no disintegration below 7 feet. Depth 23 feet to 29.9 feet solid rock.

Hole No. 9—Elevation 765.6—Total depth 38.2 feet; one foot soil and loose rock on surface. Total core recovery 19 feet.
From depth 1 to 17 feet the rock was more or less jointed, but the water escaped only at depth 10 to 11 feet. This section required nine feet of casing. Lost nine feet of core; 9 to 17 feet jointed with water stains. No disintegration. In the section, depth 17 to 32 feet, the rock was jointed, but no water escaped. From 32 to 38.2 feet the rock was solid.

Hole No. 10—Elevation 810.0—Total depth 30 feet overburden three feet. Lost core to 9 feet.
From depth 3 feet to 21 feet jointed rock was encountered and required sixteen feet of casing. The water escaped at depth 9 to 10 feet. The core recovery in this section was six feet. From 21 to 30 feet massive amphibolite was encountered with nine feet of core recovery.





I OF

LL BORINGS

DAM SITE

IVER

IN 1922

to the massive rock bands, which would resist erosion and require only a structure to retain it from working around to the toe of the dam.

The stream bed gravels and sand above and below the dam site provide a near-by source of construction material.

SUMMARY OF DATA RELATING TO DIAMOND DRILL EXPLORATIONS OF PINE FLAT DAM SITE, WITH CORE ANALYSIS

Hole No. 1—Elevation 554.8—Total depth 100 feet; core recovery 95 feet; broken to five foot joints clean and tight; some quartz filing.
Material—Massive amphibolite encountered three feet below surface. Lost two feet of core 46–60; one water stained joint; no disintegration.

Hole No. 2—Elevation 552.8—Total depth 100 feet; core recovery 93 feet; 0–5 feet cased; lost core 10–12 feet.
Material—Massive amphibolite encountered two feet below surface. Lost core 24–25 feet broken by quartz veins. Lost core 52–54 feet broken and creviced, no signs of water.

Hole No. 3—Elevation 563.2—Total depth 120.5 feet; core recovery 116.6 feet; 0–4 feet cased; lost 2 feet of core.
Material—Massive amphibolite encountered two feet below surface. Creviced at 17 feet, 18½ feet, 29 feet and 30 feet, but no sign of water; probably coarser less altered rock; 24–27 feet lost two feet of core, broken and creviced.

Hole No. 4—Elevation 562.2—Total depth 120.6 feet; core recovery 116.7 feet; no core to 7½ feet, jointed rock; some disintegration.
Material—Broken and considerably water stained joints first twelve feet and somwhat jointed to 27½ foot depth, remainder massive amphibolite. This hole required 27 feet of casing. Joints reported at 90, 96, 101 and 102½ feet; some slight water stain at 101 feet, but joint walls are stable rock; no disintegration.

Hole No. 5—Elevation 569.02—Total depth 33.8 feet; core recovery 29.9 feet; lost three feet of core 0–16 feet.
Material—Massive amphibolite two feet below surface; joints to 9–15 feet all healed closed features.

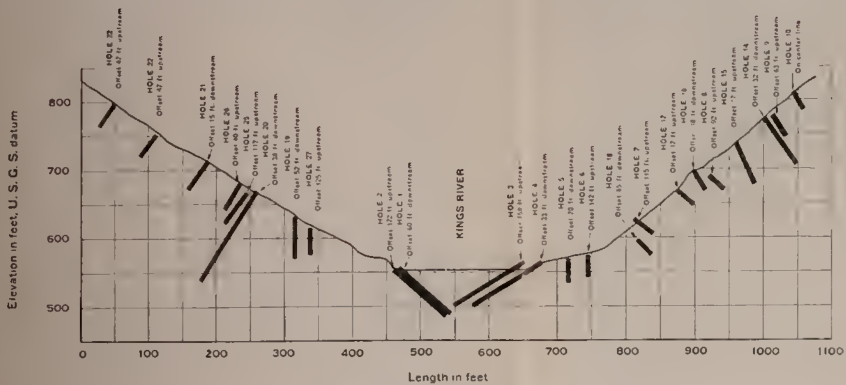
Hole No. 6—Elevation 573.4—Total depth 30.9 feet; two feet of soil at surface. Total core recovery sixteen and nine-tenths feet. Lost three feet of core 17–30 feet.
The upper fourteen feet of this hole was thoroughly broken by joints. Lost seven feet of core through which a casing was necessary. The rock below this point was hard amphibolite, but somewhat jointed, resulting in broken cores, but joints were clean, tight and probably would refuse grout.

Hole No. 7—Elevation 596.1—Total depth 30.5 feet; core recovery 26 feet; lost first three feet jointed.
Material—Massive amphibolite below 5 feet.

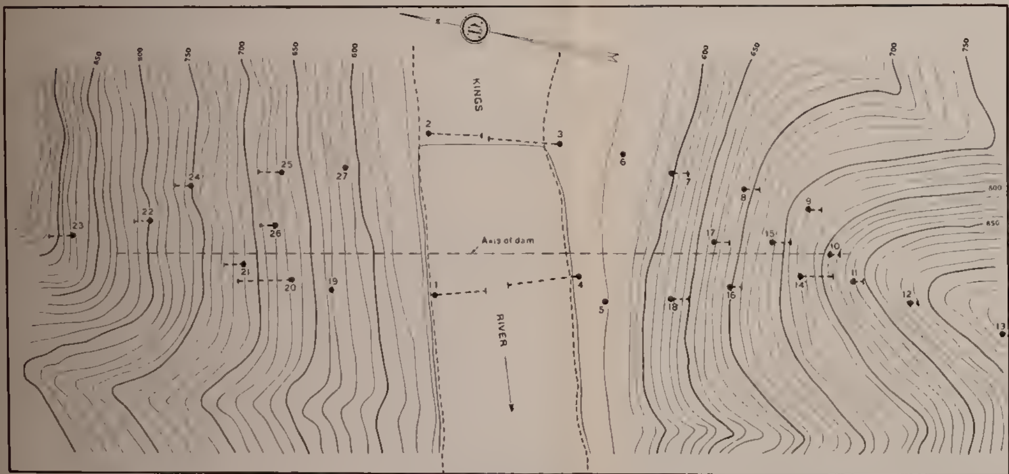
Hole No. 8—Elevation 688.4—Total depth 29.9 feet; two feet clay and disintegrated rock at surface. Below this two feet of broken and creviced rock requiring, in all, four feet of casing.
From 4 to 14 feet, rock somewhat jointed and at depth 5 to 6 feet the water escaped. Below at depth 14 feet to 23 feet, seven feet of core recovered. Broken and jointed between depths 16 to 17 feet. No water stains, no disintegration below 7 feet. Depth 23 feet to 29.9 feet solid rock.

Hole No. 9—Elevation 765.6—Total depth 38.2 feet; one foot soil and loose rock on surface. Total core recovery 19 feet.
From depth 1 to 17 feet the rock was more or less jointed, but the water escaped only at depth 10 to 11 feet. This section required nine feet of casing. Lost nine feet of core; 9 to 17 feet jointed with water stains. No disintegration. In the section, depth 17 to 32 feet, the rock was jointed, but no water escaped. From 32 to 38.2 feet the rock was solid.

Hole No. 10—Elevation 810.0—Total depth 30 feet overburden three feet. Lost core to 9 feet.
From depth 3 feet to 21 feet jointed rock was encountered and required sixteen feet of casing. The water escaped at depth 9 to 10 feet. The core recovery in this section was six feet. From 21 to 30 feet massive amphibolite was encountered with nine feet of core recovery.



PROFILE ALONG AXIS OF DAM
LOOKING UPSTREAM



PLAN OF DRILL HOLES

FEET
0 100 200

LOCATION OF

DIAMOND DRILL BORINGS

AT

PINE FLAT DAM SITE

ON

KINGS RIVER

BORINGS MADE IN 1922

Hole No. 11—Elevation 837.7—Total depth 30.5 feet. Overburden three feet. Lost core to 12 feet.
To a depth of 22 feet the rock was somewhat jointed and the water escaped at 22 feet. From 22 feet to 30.5 feet the formation was massive amphibolite carrying dikes of granodiorite. The hole required eleven feet of casing and the core recovery was eighteen feet.

Hole No. 12—Elevation 882.2—Total depth 30.6 feet. Overburden three feet. No core to 4.5 feet.
Below 7 feet depth massive amphibolite. Core recovered sixteen and seven-tenths feet. Rock shatters along joints in drilling. Lost core 24–28 feet.

Hole No. 13—Elevation 929.0—This hole is at the extreme south end of the dam site and was drilled to a depth of 68.3 feet. First 30 feet of depth in creviced and more or less broken granitic rocks. Below 30 feet hard solid granodiorite and amphibolite.
A log of the hole shows: No core to 13 feet; 13 feet to 30 feet, granodiorite; some disintegration to 14 feet and water stained joints to 29 feet; 30 feet to 31 feet, greenstone, no veins; 31 feet to 40 feet, granite with greenstone veins; 40 feet to 47 feet, greenstone (amphibolite); 47 feet to 48½ feet, lost core; 48½ feet to 50 feet, granite; 50 feet to 50½ feet, greenstone; 50½ feet to 68.3 feet, granite, one vein of greenstone. The hole required thirteen feet of casing and core recovery was 53.3 feet. Core shows gradual merging of unaltered with altered rock.

Hole No. 14—Elevation 771.2—Total depth 80.2 feet. Lost core to 15 feet.
In this hole the drillers encountered broken and jointed rock to a depth of 58 feet. The water escaped several times and a total of 20 feet of casing was necessary. Joints were water stained and rock parted along joints 15 to 20 feet. The core recovery in this 58 foot depth was 22.5 feet. From 58 feet to 80.2 feet the formation was solid and the core recovery is seventeen feet.

Hole No. 15—Elevation 736.4—Total depth 65.8 feet. No core to 30 feet.
The first 30 feet was broken, jointed and disintegrated, with only one foot core recovery. The water escaped and 30 feet of casing was required. Between 30 and 54 feet the stone was better, the core recovery being nineteen feet. Granodiorite veins from 40 to 50 feet. From 54 to 65.8 feet the formation was solid amphibolite with eleven feet core recovery.

Hole No. 16—Elevation 697.4—Total 34.2 feet. No core to 6 feet.
Overburden four feet required four feet of casing. Balance of hole was massive amphibolite and the core recovery 28 feet.

Hole No. 17—Elevation 667.7—Total depth 30.5 feet. No core to seven feet.
The overburden in this hole was five feet and the rock was somewhat creviced to a depth of 8 feet. The water escaped at 8 foot depth, seven feet of casing was required. Below the 8 foot point massive amphibolite was encountered. The core recovery was 23.6 feet.

Hole No. 18—Elevation 626.7—Total depth 34.2 feet. No core to 10 feet.
Overburden of soil and boulders six feet. Between 6 and 15 feet depth the core recovery was five feet, the rock was broken and creviced and 15.8 feet of casing was necessary. Below this point the material was solid greenstone with a full core recovery.

Hole No. 19—Elevation 631.0—Total depth 60 feet. Drilled vertically. This hole is on the north side of the canyon just at the north side of the road.
Overburden of boulders and soil eight feet. In the first 26 feet drilled the rock was jointed, some heavy water stains with disintegration. Only twelve feet of core was recovered and sixteen feet of casing was necessary. From 26 feet to 34 feet the rock was somewhat jointed, slightly water stained, but fourteen and one-half feet of core was recovered. From 34 feet to 60 feet massive amphibolite with seventeen feet core recovery.

Hole No. 20—Elevation 668.2—Total depth 153.8 feet. No core to 13 feet.
Overburden four feet. The rock encountered in the first 25 feet of this hole was very broken and jointed, the water escaped at seventeen feet, and 24 feet of casing was necessary. Below this point and to a depth of 40 feet the rock was jointed, but held the water. From 40 feet to 153.8 massive amphibolite was encountered.
Eight and five-tenths feet of core was recovered in first 24 feet, 52.5 feet of core was recovered in the next 106 feet, and a full recovery of 23.9 feet in the remainder of the hole.

Hole No. 21—Elevation 711.2—Total depth 48.6 feet. No core to seven feet.
Overburden four feet underlaid with three feet of broken and creviced rock, all requiring seven feet of casing. From 7 feet to 20 feet solid rock was encountered with a full core recovery. From 20 feet to 25 feet the stone was jointed, but no water escaped and joints were not water stained. From 25 to 35 feet the rock was solid, and a full recovery was made.
From 35 feet to 37 feet the rock was jointed, but no water escaped. From 37 feet to 48.6 feet the material was solid. A core recovery of 9 feet was made from 35 feet to 48.6 feet.

Hole No. 22—Elevation 799.9—Total depth 41 feet. No core to 9 feet.
Overburden and loose rock seven feet. The rock encountered below 7 feet was somewhat disintegrated for two feet, thus nine feet of casing was required. Below the two feet all of the material encountered was solid, with a core recovery of 24 feet in a distance drilled of 32 feet.

Hole No. 23—Elevation 875.1—Total depth 100.2 feet. No core to 19 feet.
This hole was at the extreme north end of the dam site and was drilled to a total depth of 100 feet because of a peculiarity in the formation above the dam site in this barrier.
Overburden seven feet. Underneath the overburden a somewhat broken and jointed amphibolite was encountered and nineteen feet of casing was required. At a depth of about 20 feet the solid rock was encountered and was found to be continuous to the bottom of the hole. The total core recovery was 66.5 feet. Twenty-eight to 33 feet was granodiorite jointed and slightly water stained, with full core recovery; 33 feet to 100.2 feet was massive amphibolite.

Hole No. 24—Elevation 751.8—Total depth 40.2 feet. No core to 8 feet.
Overburden five feet. From 5 to 20 feet the rock was somewhat broken and jointed and a total of eight feet of casing was necessary. The core recovery in this section amounted to eight feet. The joints were not water stained. From 20 feet to 40.2 feet the core recovery amounted to eighteen feet, and the material encountered was massive amphibolite, throughout.

Hole No. 25—Elevation 665.3—Total depth 54.9 feet. No core to 12 feet.
Overburden six feet. From 6 to 18 feet more or less broken and jointed rock was encountered, requiring twelve feet of casing. The total core recovery in this section was two feet. From 18 to 44 feet the rock encountered was reasonably solid and the core recovery was fourteen feet. From 44 to 43.9 feet massive amphibolite was encountered and the core recovery was nine feet.

Hole No. 26—Elevation 678.2—Total depth 42.4 feet. No core to 4 feet.
Overburden three feet. From 3 to 40.2 feet solid rock was encountered. The total core recovery of 34 feet made with no parting along joints.

Hole No. 27—Elevation 613.4—Total depth 33.8 feet. No core to 14 feet.
Overburden seven feet. From 7 to 13 feet a decomposed and jointed rock was encountered which required thirteen feet of casing. From 13 to 33.8 feet massive amphibolite was encountered and a core recovery of thirteen feet made.

WARD DAM SITE ON KAWEAH RIVER AND PLEASANT VALLEY DAM SITE ON TULE RIVER

The Kaweah and Tule rivers drain watersheds consisting of rugged mountainous areas whose steep slopes end abruptly, with but small extent of foothill area, in a delta of alluvial materials built up in a topographic depression by the distributaries of these two streams. The accumulation of alluvium has partially or completely buried the foothill range and the preexisting gorges between foothill outcrops are known to be filled with as much as 400 feet of stream deposits at five miles distance from the present mouth of the stream canyons. The stream history of these rivers varies from that of the Sacramento and northerly lying San Joaquin tributaries in that they have been and are now aggrading streams from the mouth of their canyons, building up extensive land bodies which, merging together, form an alluvial fan of considerable extent and depth.

General Geology.

The Ward dam and reservoir sites on the Kaweah River and the Pleasant Valley dam and reservoir sites on the Tule River, lie wholly within an area comprised of granitic rock which was an extensive intrusion into the early (pre-Jurassic time) crustal rocks. This intrusion of the mass more or less changed the original rock crust so that where peridotites existed we now find serpentines; sedimentary limestones now exist as crystalline limestone; shales became slates; and a variety of rocks became "greenstone." These changed rocks make up the foothills of the region examined. They have been partially buried by stream deposits, having been attacked by the weather to produce the "red-lands" soil which borders the mountains and lies between alluvial soil areas, and are distinguished by their smooth, gently sloping surface in contrast to the rocky slopes developed in the granitic rock.

Geologic Structure.

The topographic development at the dam sites is due to differential weathering upon a massive body of crystalline rock varying widely in texture. In places the mass has developed gneissic and somewhat schistose structure, which probably indicates old crustal adjustments accompanied by shear, now long completed, and the fractures and shear zones are thoroughly healed by quartz deposition. The later jointing, which is a common structural feature of all Sierra Nevada rocks, is evidenced here by a complex series of irregular joint planes. The weathering of the rock along these joint planes has developed the "rocky" slopes characteristic of the granitic areas of the region. There are no active faults to be found in the vicinity of the dam sites, the nearest known fault being a profound structural feature passing through the eastern half of Tulare Lake bed and buried by alluvium.

Detailed Geology—Ward Dam Site.

The Ward dam site, shown on Plate C-XIII, is located at a point on the Kaweah River channel where erosion has carried the stream trench well into a massive crystalline rock—granodiorite. The rock at the dam site consists principally of quartz, feldspar and hornblende crystals, and the crystalline texture varies from fine-grained granodiorite to coarse-grained gabbro-diorite or hornblende gabbro. Mica is lacking in some phases, but small localized areas contain abundant mica. It is the massive and strong rock commonly called granite.

Granite, however, has not the durability generally conceded it. Upon the cooling of the original molten material, relatively large crystals of quartz, feldspars and ferro-magnesium minerals formed and interlocked with each other until the whole became converted into a "patchwork" of interlocking crystals, firmly knit into a strong crystalline mass. With the forces of weathering, this crystal fabric is subject to breakdown through the unequal expansion and contraction of the component crystals under temperature changes and the chemical and mechanical work of moisture penetrating into the rock through the crystal partings. The fine textured granite is more resistant to weathering, the surface rock spalling off in layers and leaving rounded outcrops. The coarse textured granite, however, is subject to disintegration to a much greater degree and far below ground-surface, leaving a residuum of so-called rotten granite over the unweathered rock. Rotten granite is a physically weak crumbly mass, subject to penetration and percolation of water and readily eroded.

The dam site is located wholly within the granite mass, with the topographic differences due to the effect of erosion and the weather upon the rock of fairly uniform hardness rather than dependent upon structural features. The granite mass has developed several systems of joints, the principal one striking north 50 to 70 degrees west and dipping nearly vertical, being intersected by one dipping south about 50 degrees, west about 40 degrees, and a complex system of minor joints.

The south abutment consists of large unweathered outcrops representing sound joint blocks, which may or may not be found to be displaced, bordered by blocks which have completely disintegrated and broken down to a sandy residuum. It contains several benches of heavy soil cover between outcrops of rock. The higher slope consists of rock in place, which has disintegrated along joint planes. Most of the outcrops are joint blocks. They have been somewhat displaced at the surface and the joint walls have parted, leaving openings along which water enters the mass to carry on chemical activity. This activity results in a decomposition of some of the mineral constituents, and mechanical action which removes the weakened or "rotted" joint walls and further enlarges the openings.

The effect of weathering along joint planes is plainly discernible in a fresh road-cut at which the firm sound rock was drilled to a depth of ten to twelve feet and shot, revealing a disintegrated zone along a joint plane from which the crumbly mass readily can be picked out.

Most of the joints in the fresh rock at stream bed were found to be closed and healed with quartz. However, it is quite possible disintegration may have extended along joint planes to considerable depths below dam foundation. Experience had in drilling exploration of similar rock leads to the conclusion that water has been in circulation through the rock along the joint planes and this circulation would be

PLATE C–XIII

GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
WARD DAM SITE
ON
KAWEAH RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Grano-diorite

increased upon construction of a dam, allowing leakage under and around a dam and possibly uplift on it. The walls of some of the joints may be found to be sound, although water stained, indicating closed fractures, but on the whole it may be classed as seamy rock with the stable products of disintegration—the sand—left in the joint cavities which would make it difficult to seal by grouting.

The lower portion of the north abutment it made up of slabs of fairly sound rock, from which the active erosion of the stream has carried much of the residuum and left steep side slopes. These rock slabs vary from four to ten feet in thickness and are formed by the "spalling" of the rock along joint planes parallel to the slope—dipping north 60 degrees, east about 20 degrees. The upper portion of the abutment is similar to that of the south side.

The uncertainties of the results of the attack of the weather upon and the circulation of water through this type of rock make it impossible to predict with any certainty the extent of stripping and pressure grouting which would be necessary. The fresh road-cut shows twelve to fifteen feet of soil cover, three feet of completely disintegrated rock, then sound rock with disintegrated zones along joint planes. For preliminary estimate purposes only, it should be considered that the stripping will be uneven, and allowance made for at least 25 feet excavation perpendicular to the slope on the average over the entire site. If the economic features thus arrived at warrant further consideration of the site for construction of a dam, the abutments and stream bed should be drilled and tested by water under pressure in accordance with the location, inclination and extent of joints revealed upon partial stripping and test pitting and tunneling the site.

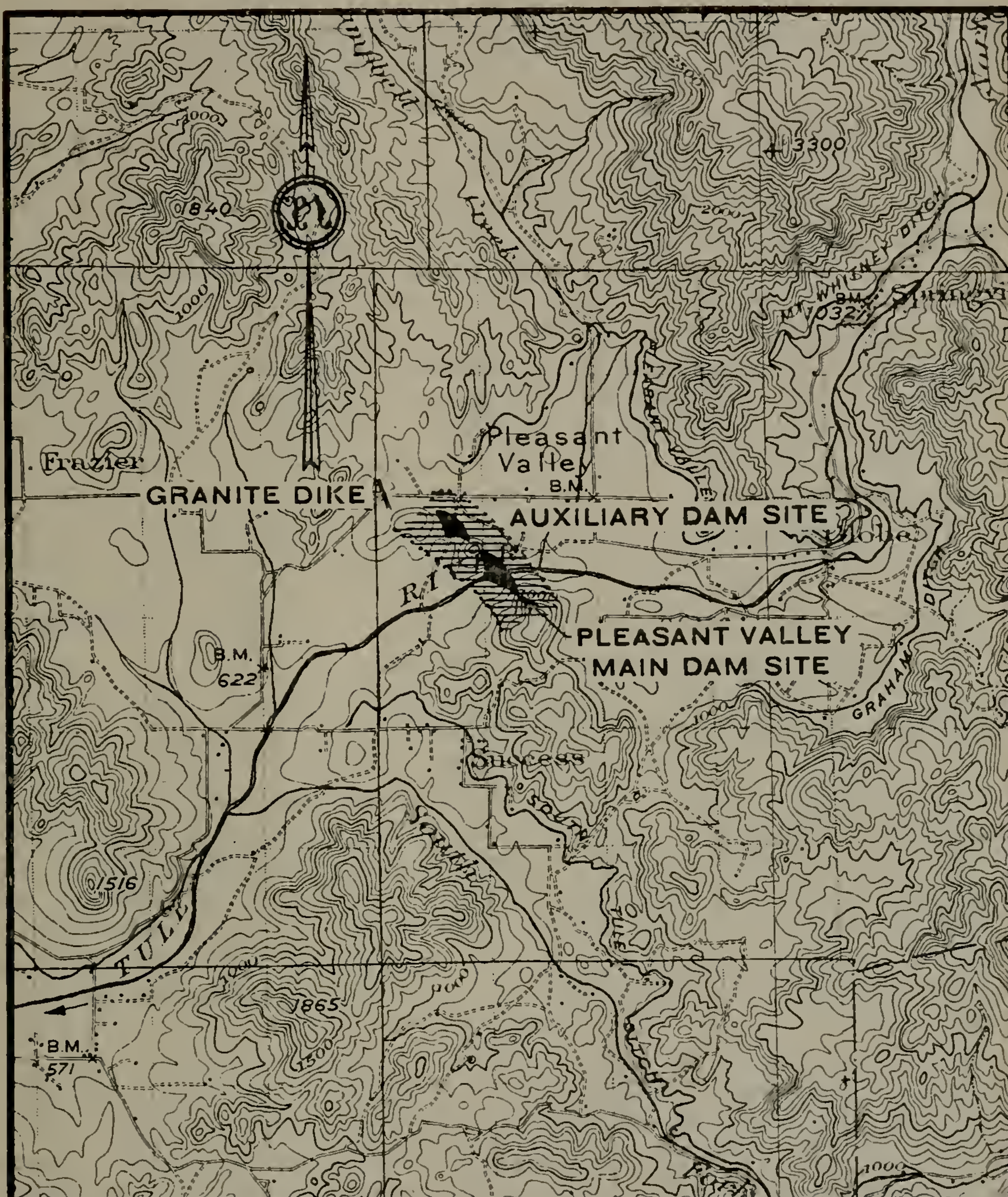
There is no question that if sound granite can be found at reasonable depth that, with reasonable preparation, a concrete arch or gravity type dam could be constructed on the site. There is no natural spillway available so the spillway should be part of the structure. Construction material is available in the stream bed above and below the site.

Detailed Geology—Pleasant Valley Reservoir.

Pleasant Valley is a fairly extensive area of flat land lying between 700 and 800 feet above sea level in Township 21 South, Range 29 East, M. D. B. and M. The surface of the area is made up largely of stream deposited sand and gravel with some coarse boulder areas. Tule River has intrenched itself in this material through the area and, at its westerly limit, has cut about 50 to 60 feet below the adjoining gravel and boulder bench lands. The area could be enclosed through construction of a main dam across the river channel at the east line of section 18 and two auxiliary dams across low areas in the north half of the same section, but the topographic development is such that little storage could be obtained for the lower section of the main dam. The site and geology of the location are shown on Plate C-XIV.

The bed rock of the region, including the dam sites, consists of granitic rock varying in texture and mineral constituents within comparatively small areas. The north abutment of the main dam site is made up of a coarse textured rock consisting principally of hornblende and feldspars, which might be designated diorite. The same rock, with some granodiorite phases, extends northwesterly through the site of

PLATE C–XIV



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
PLEASANT VALLEY DAM SITE
ON
TULE RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Granitic bed rock covered with stream-deposited sand and gravel the required Auxiliary Dam. A dike of true granite strikes north 30 degrees west through the axis of the proposed auxiliary dam. The south abutment at the main dam site consists principally of close textured grano-diorite outcrops, but as the texture phases change over the region it is probable coarse-textured rock lies below the soil cover. This abutment carries some terrace gravels and remnants of a lava flow. The rock is massive in structure and when sound has great strength. It is considerably jointed and the mass is weakened by disintegration of joint wall rock.

Weathering has attacked the rock, producing gentle slopes at the main dam site abutments. The rock outcrops are principally dislodged jointed blocks with but little rock found in place. The rock on the north abutment, being coarsely crystalline, has disintegrated to considerable depth. An average allowance of 50 feet depth of stripping over the whole site would probably not be excessive as there are no outcrops over the stream bed, but a wide flood plain bordered by terrace gravels.

The auxiliary dam site would require a 45-foot structure. The coarsely crystalline rock found here has weathered deeply to produce gentle slopes. It is probable an earth fill structure here would require a cut-off reaching to sound rock at 50 to 60 feet below ground surface to prevent leakage through the porous residuum.

ISABELLA, BOREL AND BAKERSFIELD DAM SITES ON KERN RIVER

Kern River drains the southern end of the Sierra Nevada and is the most southerly master stream entering the San Joaquin Valley. The Kern River region presents geologic and topographic conditions which vary greatly from those obtaining over the regions examined in connection with dam sites located on the northerly lying Sierra streams. It emerges from its foothill region at Bakersfield and flows southwesterly over an alluvial fan built up in a topographic depression formed by fault displacement, terminating in a flat area formerly occupied by large fresh water bodies—Kern Lake and Buena Vista Lake.

The foothill belt, extending from Bakersfield to the mouth of Kern Canyon, is comprised of loosely cemented sandstone, conglomerate and shale beds of Tertiary age, overlaid in part by an early alluvial fan of the Kern River. The river has intrenched itself into both these formations, cutting steep rugged walls to its trench, which, in places, rise above broad mesas representing the surface of former flood plains and the Pleistocene fan of the river. Contemporary lateral erosion and weathering has carved the material originally forming the floor of the Tertiary sea into ridges and round topped hills, leaving a portion of this surface as a mesa, but slightly eroded, south of the river.

The erosive development in the foothill region has been such that it does not provide suitable dam sites with the possible exception of the Ant Hill site in the east half of Section 5, Township 29 South, Range 29 East, and the Bakersfield site about three miles downstream.

The lower Kern River Canyon, from Kernville to its mouth, is unique among Sierra stream trenches in that the grade increases down stream. This is due to uplift of the region during time so recent that the stream has not achieved a mature profile and the base leveling processes in the more resistant rock above the mouth of the canyon have not kept pace with the erosion of the sedimentaries of the foothill region. The lateral topographic development of Kern River Canyon is due principally to the attack of the weather, resisted by petrographic differences in a granitic rock mass. Where coarse textured rock prevails the slopes are moderate, with a fairly heavy cover of disintegration products, principally coarse sand, carrying loose joint blocks differing widely in size and varying in their stage of disintegration. The finer textured rock bodies are characterized by precipitous rock slopes carrying large blocks detached from the underlying mass along joint planes, but exhibiting no appreciable rock decay upon their surfaces or along joint walls.

Two areas of the latter rock occurring below Isabella were examined in detail, the upper in Section 36, Township 26 South, Range 32 East, in which the Isabella dam site is located, and the lower in Section 32, Township 27 South, Range 31 East, in which the Borel dam site is located. At these two locations the stream crosses what might be termed dykes of close textured rock at right angles to the strike and the topographic development has provided a "V" shaped stream trench well adapted to dam site purposes.

General Geology.

The greater portion of the rock through which Kern River has cut its canyon below the junction of the South Fork with the North Fork may be designated a coarse-grained, light colored granite, showing numerous large phenocrysts of feldspar (probably orthoclase). Included in this granite mass are areas of medium to close-grained grano-diorite having fairly uniform texture and consisting principally of feldspar, quartz, mica, (biotite) and hornblende. Besides these two main facies, the rock throughout its mass varies in color and texture gradations in small irregular bodies, due to local differences in feldspars and inclusions of a multitude of small hornblende crystals, and contains dykes or veins of light colored aplites varying in width from less than one to about five feet.

The granitic core of the Sierra Nevada is predominate in this region and probably represents huge batholithic intrusions in contrast to the plug or dyke from plug intrusions in the older (pre-Jurassic time) crustal rocks which characterize the occurrence of granitic rock in the northern Sierra. At the southern end of Hot Springs Valley and up South Fork Valley are limited areas of the older crustal or metamorphic rocks (including limestone) which can be distinguished by the reddish brown color and smooth surface they develop under weathering, in contrast with the light colored rocky slopes of the granite. They do not, however, reach the Kern River channel at any point below Kernville.

The batholithic intrusions probably carry as far north as the San Joaquin River, and it appeared there (in contrasting the rock at the Fort Miller dam site with that at the Temperance Flat dam site) as well as on the Kern River that the enormous intrusion was a progressive action giving rise to a series of granitic intrusive bodies of somewhat different age and having different texture characteristics. The close textured grano-diorite bodies have a "fresher" appearance, a more even crystalline texture, and are more resistant to the attack of the weather; therefore, they make the more favorable rock for dam foundation.

The Tertiary rocks comprising the foothill region are part of a belt exposed along the southern border of the San Joaquin Valley, from the Temblor Range on the west to, and flanking, the southern end of the Sierra Nevada on the east, and are geologically similar to the foothill belt north of the San Joaquin River. The Tertiary rock belt of the San Joaquin Valley is a thickness of clastic material in excess of 20,000 feet which consists largely of marine sediments, but which contains continental deposits and volcanic ash beds in its upper portions.

The Pleistocene deposits consist of continental accumulations of stream-laid detritus overlying the Tertiary rocks.

Geologic Structure.

The Kern River region may be said to be the connecting link between two major structural provinces of California—the Southern California-Coast Range province and the Great Valley-Sierra Nevada province—provinces whose geologic as well as structural characteristics are widely divergent. It lies within the area of influence of geologically recent rifting. The San Andreas rift, California's most extensive and still active fault rift, passes southeasterly from the San Francisco Bay region through the heart of the Diablo-Temblor Range and through the Carrizo Plain, to swing more easterly south of Bakersfield. A great number of complex faults along which the earth's crust has been displaced and between which the sedimentary rocks have been folded, run out from this rift.

The observed faults consist of one at the mouth of Kern River Canyon, paralleling the strike of the main granite ridge and separating it from the Tertiary sediments, and one passing through Hot Springs Valley from Kernville to Bodfish, which appears to be continuous with the profound fault line along which the North Fork of the Kern has developed and to be continuous through Walker Basin, Caliente and along the base of the El Tejon ridge. Many minor faults probably exist, though not readily discernible because of the rock on both sides of the fault having the same characteristics and because the topographic development originated before much of the displacement occurred and has progressed along the original lines in spite of the displacement. The valleys, such as Hot Springs Valley and Walker Basin, are probably features originating at the result of the major fault displacement and their erosional and depositional history has been controlled by the rift line, but the lower canyon of the Kern River is due to stream erosion established before the displacement occurred and maintained during the period of displacement and it is separated from the rift line by an intervening ridge of sound rock.

All the granitic rocks of the lower Kern River Canyon exhibit jointing. The joints are approximately horizontal and vertical and the joint blocks are more or less rectangular or slabs. The joints are more abundantly developed near the mouth of the canyon, due to compressive stresses set up in faulting along the line previously described. The same holds true between Isabella and Kernville where a major fault passes from Hot Springs Valley up the North Fork of the Kern. The east front of the ridge separating the Kern River trench from Hot Springs Valley is a fault scarp modified by erosion.

Detailed Geology—Isabella Dam Site.

Two proposed dam sites near Isabella were examined. The upper, or "A" site, lying in Section 19, Township 26 South, Range 33 East, is that referred to and indicated upon Map 4, in Bulletin No. 9*. The lower, or "B" site, (previously located) is that which the proposed Kern River Water Storage District sought to utilize. They are shown on Plate C-XV. Both sites would flood the North and South Fork Valleys and require an earth embankment across Hot Springs Valley to retain 350,000 acre-feet storage. The "B" site is more favorable, from both geologic and topographic standpoints, for construction of a high concrete structure.

The bedrock at both sites consists of close textured grano-diorite. The rock is jointed, but the jointing at the "A" site is more abundant and the rock is weakened because of its proximity (within one-half mile) to the Hot Springs Valley fault. Erosive action of the Kern River at the "A" site has been such as to cut into the weakened mass and remove much of the "blocky" material until a "U" shaped stream trench has been carved out. The slopes are moderate with loosened blocks and sandy residuum at lower levels and some higher benches carrying a heavy soil cover of wind-blown sand.

The "B" site is further removed from the rift line and exhibits less jointing, so the rock is sound and strong. The stream trench is "V" shaped, with fresh rock, somewhat pothollithic, making up the walls. The stream bed contains some large joint blocks around which have lodged gravel and boulders.

The joint systems consist of main vertical joints running east and west, crossed by a north and south system dipping almost vertical. The mass contains aplite veins or dykes which are continuous on both sides of the stream trench and dip about north 60 degrees west from 20 to 25 degrees. The erosive development of the left, or east, abutment has been controlled somewhat by these veins and the rock has jointed as the vein contacts. The north and south joint system has controlled the erosive development of the right, or west, abutment. Large joint blocks are displaced from the mass, but the joint walls are clean, unweathered sound rock. It is probable that few, if any, joints would be found open upon uncovering stream bed rock and there is little likelihood of leakage under a dam or uplift upon it.

The displaced joint blocks on the abutments would necessarily be removed in stripping the site. Some joints may be found which open without appreciable displacement of the joint blocks, but the mass could be rendered sound by grouting. The upper abutments carry some disintergrated joint blocks and a light soil cover. On the average, 20 feet of stripping should provide sound rock foundation.

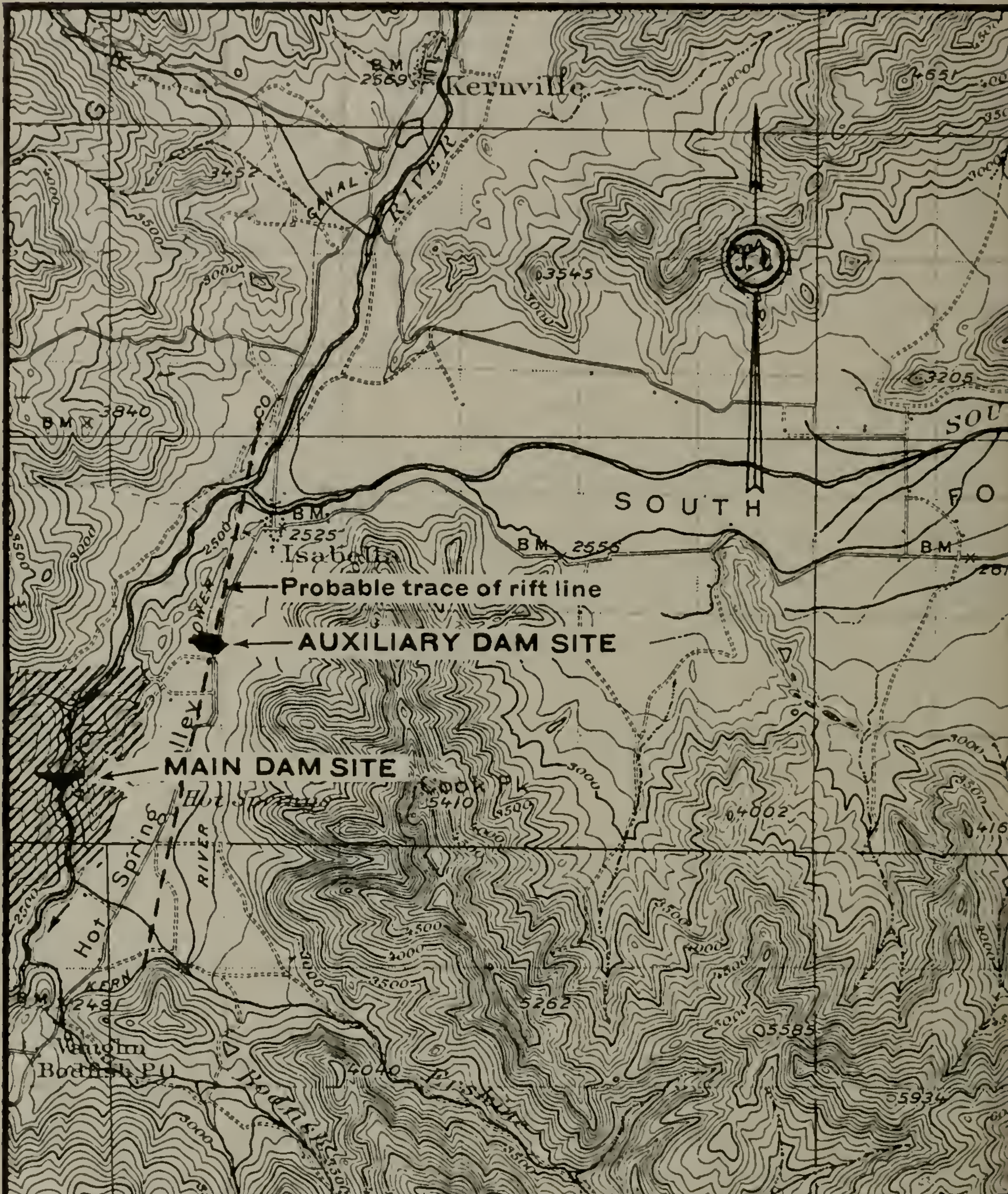
The site is well suited to a high concrete arch structure. No natural spillway is available, so spill must be had through overflow of dam. Construction material can be obtained by crushing at the site or from the North and South Fork Valleys upstream.

Auxiliary Dam Site, B-1. The storage requirement necessitates an embankment in Hot Springs Valley. The location B-1, shown in

---

* Bulletin No. 9, "Water Resources of Kern River and adjacent streams and their utilization," Department of Engineering, State of California, 1920.

PLATE C–XV



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES
IN THE VICINITY OF
ISABELLA DAM SITE
ON
KERN RIVER

SCALE OF MILES

0 1 2 3 4

LEGEND

Close textured grano-diorite

Plate C-XV, is said to have been drilled and shown to have water-bearing sand to 110 feet and blue clay to 255 feet. The geologic history of the valley filling would lead to the conclusion that bedrock would not be found within reach of a cut-off wall, except possibly at Isabella. At the latter point the rock would lie within the shear zone of the rift and would probably contain open fractures which would pass water more freely than alluvium. Considering that the height of the embankment would only be 60 feet maximum and that some leakage loss is allowable, it seems more desirable to locate an earthen dam at B-1, providing a broad base so that possibility of mechanical piping through the alluvium would be reduced to a minimum.

Detailed Geology—Borel Dam Site.

Two dam sites, ''A'' and ''B,'' shown on Plate C-XVI, were examined at Borel. The river takes a westerly course to about 400 feet above the present diversion dam, then swings southerly to a point about 1000 feet below the dam, thence turns westerly. This is due to the control exercised by a close textured grano-diorite dyke conspicuous in an area of coarse textured rock. The dyke rock is not so finely crystalline as at Isabella, but is sufficiently resistant to the attack of the weather and stream corrosion that the stream has taken the shortest course across it, and cliff profiles are developed in contrast to the heavy soil covered gentle slopes above and below the dyke.

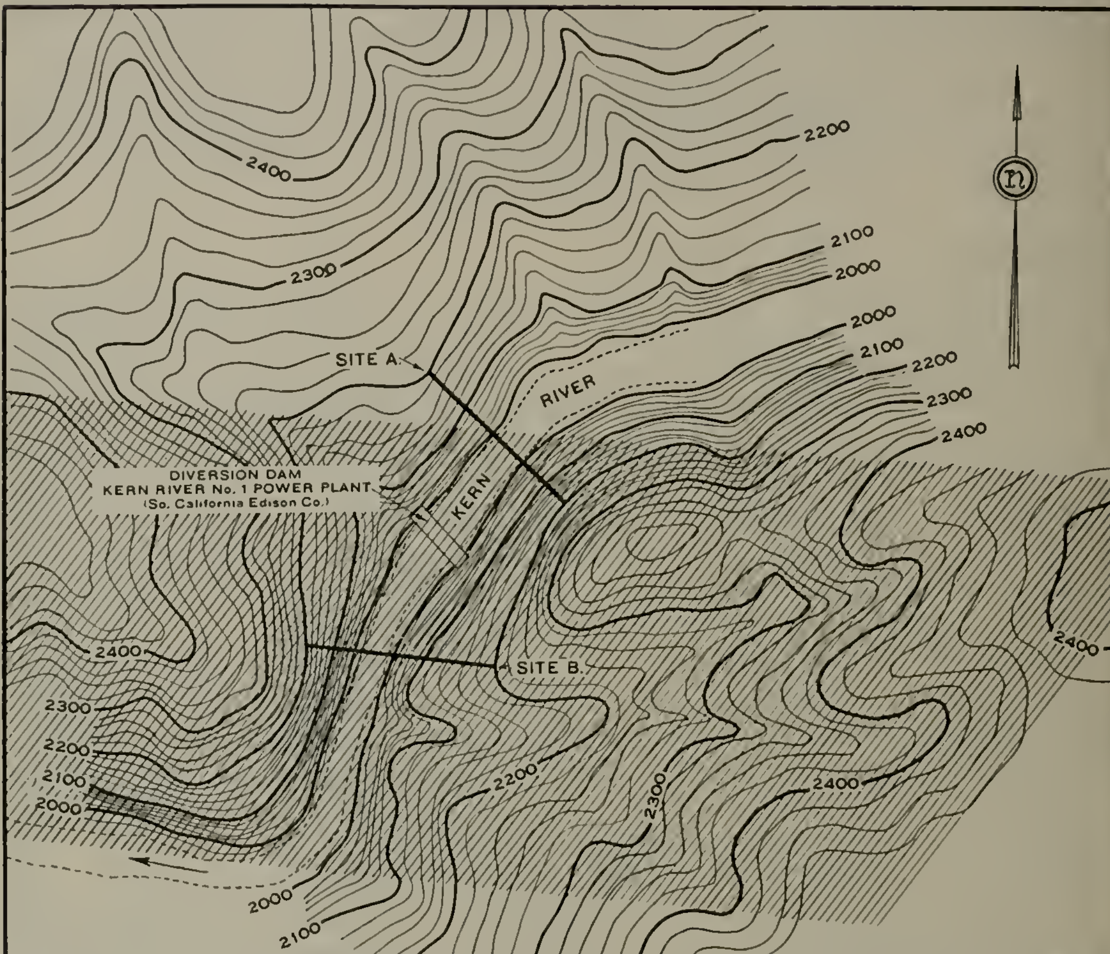
Dam site ''A'' crosses out of the close textured rock into coarse textured rock so that the right abutment carries a heavy soil cover. The left abutment rock is considerably jointed, moderately weathered along joint planes, and large joint blocks are displaced near stream level. The upper portion of the abutment contains rock exposures in a heavy soil cover, but these are probably all displaced blocks. The stream channel deposit is excessive in depth due to the diversion dam.

A more favorable site, ''B,'' lies about 300 feet downstream from the diversion dam. Here the cliff profile is well developed to 100 feet above stream bed and rock outcrops more continuously to the crest of the ridge, with but shallow soil cover. The rock is moderately jointed, with the main vertical joints striking at right angles to the strike of the dyke. Some joint blocks would have to be removed, but on the average fifteen feet excavation for a 200 foot dam and 20 feet excavation for a higher dam should cover requirements. The joints in the cliff face, and at stream bed are tight closed features. Grout preparation might be required on the upper abutments to close joints there. On the whole the site is entirely satisfactory for a 200 foot or even higher concrete arch dam.

Consideration of Design to Meet Earthquake Possibilities.

The fact that the region studied is one that has, in times past, been subjected to seismic disturbances has been previously noted. The faults passings through the region near the Kern River dam sites have been considered long dead and are so indicated upon the Fault Map of the state. However, the San Andreas Rift is active and it is not beyond the range of probabilities that seismic disturbances again will affect the region in a minor way and should be amply guarded against in the design of structures.

PLATE C–XVI



GENERAL TOPOGRAPHIC AND GEOLOGIC FEATURES

IN THE VICINITY OF

BOREL DAM SITE

ON

KERN RIVER

FEET

0 400 800 1200 1600

LEGEND

Close textured grano-diorite in coarse textured granitic rock

The conclusion that concrete arch dams could be safely constructed at the Isabella and Borel sites is based upon the fact that no fault line passes through them and that they would be subject to no earth movement other than tremors or shock waves. Concrete structures in the vicinity of the San Andreas fault successfully withstood the intense earthquake shock of 1906, but if there is anything which makes arch dams less resistant to earth tremors than other types of dams, a gravity type or even a rock fill type, for which there is ample material available, should be selected.

Detailed Geology—Bakersfield Dam Sites.

The Tertiary rocks which make up the foothill region and which would form the reservoir bed and dam foundation of any structure placed in Kern River between the mouth of Kern Canyon and Bakersfield, are permeable and to some extent soluble. They dip slightly downstream southwestward, and present the least favorable structure to seepage from a reservoir. Overlying these rocks are terrace gravels and portions of the eroded early fan of Kern River. Most of the ridges protruding into the river channel are composed of these continental deposits, so that, although the topographic features are most favorable to dam site purposes, they would have to be eliminated from consideration as foundation or abutments. The Ant Hill site was examined in detail but the geological data apply in general to the Bakersfield site.

The foundation rock, though soft and loosely cemented, when dry is sufficiently strong to bear the load of a 200 foot earthen dam, provided the dam be designed with a broad base, six to eight times the height, and the load per square foot on the foundation be moderate. Seepage through the foundation and abutments might saturate and rupture the structure of this material, however, so as to render it unfit for use.

Ordinarily porous and permeable materials underlying stream beds are saturated with water to within a reasonable depth below ground surface and there is a passage of water from the surface stream downward and laterally through the materials at rates controlled by the resistance to flow afforded by friction in the interstices of the materials. If the water surface be raised above the stream bed through construction of a dam, added head is applied over the water entering the materials, wider contact of water with materials is accomplished, and entirely new ground water conditions are set up.

In the present instance the inclosing rim of the reservoir consists of open textured, sandy and conglomeratic material containing beds of close textured material which absorbs moisture rapidly, resulting in the complete rupture of its structure. The close textured material contains shrinkage joints formed with the drying out of wet mud and these joints are filled with gypsum. Gypsum is soluble in water and its presence in the material suggests the formation of solution channels. It is not at all unlikely that the reservoir rim rock and dam foundation material would be subject to both mechanical and chemical piping. Just what the length of the path of percolation necessary to overcome such effect would be can not be foretold from the data at hand. It is said that the stream at present does not lose by seepage through the reservoir site. Furthermore, there is no apparent ground water contributions from the river through the south ridge to an area of heavy pumping draft in the Weed Patch area, although the ground water gradients are steep.

If the construction of an earth fill dam having a crest length of about 4000 feet, a height of 200 feet and a base width of six to eight times the height, is economically feasible, then additional tests are warranted. Such tests, with apparatus and routine used successfully in connection with similar problems, consist of the determination of the rate of percolation, measured in gallons per square foot of surface per hour, through a six inch column of material taken in its natural state under varying heads. Through such observations it also is possible to determine the physical changes undergone by the various types of materials when penetrated by water under pressure. Should it be determined by test that there would be little likelihood of mechanical or chemical piping under the ground water gradients obtaining upon completion of a dam, it is probable reservoir seepage losses at first would be excessive while the underlying material was being brought to the saturation point and the water table level was adjusting itself to the new conditions, but thereafter losses would be limited to replacement of water moving laterally through the ground and, through reservoir silting, might be further reduced.

APPENDIX D

ADEQUACY OF INITIAL AND ULTIMATE MAJOR UNITS OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN IN THE SEASONS 1929–30 AND 1930–31

TABLE OF CONTENTS

ADEQUACY OF INITIAL AND ULTIMATE MAJOR UNITS OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN IN THE SEASONS 1929–30 AND 1930–31

The water supply studies pertaining to the State Water Plan in the San Joaquin River Basin, as set forth in the main body of this report, are based on the estimated and measured surface run-offs which have occurred during the 40-year period extending from October 1, 1889, to October 1, 1929. This period is one of wide variability in run-off. It includes seasons of plentiful run-off and seasons of scarcity in supply. For example, in the seasons 1905–06 and 1906–07, the seasonal run-offs from the drainage basin are estimated at 23,374,000 acre-feet and 21,108,000 acre-feet, respectively, or nearly twice the estimated mean seasonal run-off for the 40-year period. In 1889–90, the seasonal run-off is estimated at 28,009,000 acre-feet, nearly two and one-half times the average for the period. On the other hand, during this period, there were seasons and consecutive seasons during which the run-off was far below the average. The season of lowest run-off for the period is 1923–24 with a run-off of 2,576,000 acre-feet. It is believed from a study of precipitation records that the latter season is one of the lowest in run-off since 1871 and probably since 1850. It should be mentioned, also, that the smallest combined run-off for periods up to five consecutive seasons, from 1871 to 1929, probably occurred during the last eight years of this 40-year period.

In the water supply studies which have been presented in this bulletin, the 40-year period 1889–1929 was analyzed in estimating the utilizable water supply obtainable, through the combined means of surface storage and underground storage and pumping, from the upper San Joaquin Valley streams to meet the needs of areas to be served in the upper San Joaquin Valley under the plan of ultimate development. Under the plan of initial development for the upper San Joaquin Valley, however, the 12-year period 1917–1929 of subnormal run-off was used as a basis for designing the units and estimating the utilizable supply obtainable because of the desirability of assuring an ample supply for adequate and immediate relief to the areas of serious water shortage even if a similar period of subnormal run-off were experienced immediately following the consummation of the initial project. The 40-year period also was used in the water supply analyses for the streams of the Sacramento and lower San Joaquin valleys in both the initial and ultimate plans of development. However, because of proposed regulation chiefly by surface storage, it was found that the critical period determining the safe yield and required capacity of surface storage units for the streams in the Sacramento and lower San Joaquin valleys was the 12-year period 1917–1929. With the exception of one small area in Hydrographic Division 8, no account was taken of the availability and possible utilization of underground storage in either the Sacramento Valley or lower San Joaquin Valley. All water supply analyses were made month by month for each season throughout the period studied. These foregoing criteria for water supply analyses were adopted at the beginning of the investigation in 1929. The results of the analyses made to test the adequacy of both initial and ultimate developments of the State Water Plan in the San Joaquin River Basin are set forth in Chapters VII and VIII.

Since the completion of the studies based on the available water supplies for the 40-year period 1889–1929 on which the major units of the State Water Plan for initial and ultimate development were proportioned, two seasons of low run-off have occurred, namely, 1929–30 and 1930–31. Therefore, it was deemed desirable to test further the adequacy of the plans proposed for initial and ultimate development in the San Joaquin River Basin by the inclusion of these seasons in the water supply analyses and, if either plan were found inadequate, to point out wherein, if possible, modifications could be made which would assure adequate supplies of water to all areas served by the plans. The results of these supplemental analyses and investigations are presented in this appendix.

There also is given herein an analysis for the San Joaquin River Basin, the Sacramento River Basin, and the combined basins, of the probability of the occurrence of seasonal run-offs of various magnitudes. This is presented for the purpose of indicating the probable frequency with which the low seasonal run-offs of the past few years might be expected to occur in the future and, therefore, of indicating further the adequacy of the plans.

Water Supply.

The water supplies—full natural, and ultimate net run-offs—from the San Joaquin River Basin streams for the seasons 1929–30 and 1930–31 were estimated by the methods described in Chapter II.

Indices of Seasonal Wetness—In order to estimate the run-offs from some of the unmeasured streams, and also to obtain a comparison of the precipitation in the seasons of 1929–30 and 1930–31 with that in other seasons and with the mean, indices of seasonal wetness were computed for the precipitation divisions lying wholly or partially in the San Joaquin River Basin. In calculating the values of these indices, the mean precipitation for each station or division was taken as that for the 50-year period 1871–1921. The indices for each division for the seasons 1929–30 and 1930–31 are shown in Table D-1 which is an extension of Table 3 in Chapter II.

TABLE D-1

INDICES OF SEASONAL WETNESS FOR SAN JOAQUIN RIVER BASIN

Season	Precipitation division							
	K	L	P	Q	R	S	*T	*V
1929–1930	75	76	70	67	75	81	62	73
1930–1931	60	63	69	74	65	98	75	88

*Indices for divisions T and V are computed for and apply particularly to those portions of these divisions lying within the San Joaquin River Basin.

Full Natural Run-offs—The seasonal full natural run-offs from the mountain and foothill drainage basins of the major streams and minor streams, or groups of minor streams, of the San Joaquin River Basin, for the seasons 1929–30 and 1930–31, are shown in Table D-2 which is an extension of Table 5 in Chapter II. Mean seasonal run-offs also are shown in the table for the 42-year period 1889–1931, the 22-year period 1909–1931, the 14-year period 1917–1931, the 10-year period 1921–1931, and the 5-year period 1926–1931.

TABLE D-2

SEASONAL FULL NATURAL RUN-OFF OF SAN JOAQUIN RIVER BASIN STREAMS

Stream or stream group	Drainage area, in square miles	Run-off, in acre-feet		Mean run-off for period, in acre-feet				
		1929–30	1930–31	1889–31	1909–31	1917–31	1921–31	1926–31
Upper San Joaquin Basin—								
Panoche Creek	295	3,100	9,400	25,400	22,600	14,200	13,200	10,700
Cantua Creek Group	208	2,200	3,300	12,100	10,600	6,200	5,900	4,600
Los Gatos Creek	119	1,300	3,200	9,000	7,800	4,800	4,500	3,600
Tejon Creek Group	1,341	12,600	36,800	85,600	70,100	44,000	43,200	35,400
Caliente Creek	471	12,600	25,100	36,400	28,000	21,500	22,600	20,100
Kern River	2,410	373,500	194,600	704,000	654,000	477,000	448,000	413,000
Poso Creek Group	576	13,800	9,200	43,900	36,200	27,000	27,800	23,700
Deer Creek	110	8,300	5,100	18,900	15,600	11,900	11,300	10,200
Tule River	390	48,100	20,600	130,000	106,000	76,500	73,200	62,300
Yokohl Creek Group	98	3,700	2,600	13,700	11,200	8,300	8,500	7,100
Kaweah River	514	217,600	114,200	430,000	338,000	283,000	271,000	248,000
Limekiln Creek Group	201	26,800	16,100	58,700	50,100	39,900	40,400	36,200
Kings River	1,694	862,800	465,800	1,830,000	1,497,000	1,222,000	1,161,000	1,027,000
Dry Creek	48	800	1,300	4,000	3,400	2,600	2,600	2,000
San Joaquin River	1,631	879,900	488,800	1,933,000	1,607,000	1,300,000	1,250,000	1,084,000
Cottonwood Creek	28	300	500	2,000	1,600	1,200	1,200	900
Fresno River	270	19,600	7,300	61,000	52,400	41,300	39,600	29,700
Daulton Creek Group	66	700	1,100	4,500	3,700	2,700	2,800	2,000
Chowchilla River	238	31,700	3,000	68,300	52,600	48,900	49,400	38,700
Totals, Upper San Joaquin Basin	10,708	2,519,400	1,408,000	5,470,500	4,567,900	3,633,000	3,476,200	3,059,200
Lower San Joaquin Basin—								
Orestimba Creek Group	1,340	28,600	21,400	116,000	95,200	76,600	74,300	47,100
Dutchman Creek Group	72	2,300	800	8,300	5,600	4,800	4,900	3,900
Mariposa Creek	103	4,400	2,200	12,800	8,800	7,800	7,800	6,400
Owens Creek Group	66	1,800	700	6,400	4,200	3,600	3,600	2,900
Bear Creek	71	2,300	800	7,500	5,000	4,300	4,300	3,500
Burns Creek Group	171	8,200	2,700	24,500	17,500	15,600	15,700	12,700
Merced River	1,054	512,800	262,300	1,080,000	893,000	745,000	722,000	616,000
Tuolumne River	1,543	1,148,900	607,200	2,014,000	1,691,000	1,453,000	1,416,000	1,262,000
Wildcat Creek Group	59	2,800	900	8,800	6,100	5,400	5,400	4,300
Stanislaus River	983	731,800	315,000	1,311,000	1,055,000	866,000	853,000	775,000
Totals, Lower San Joaquin Basin	5,462	2,443,900	1,214,000	4,589,300	3,781,400	3,182,100	3,107,000	2,733,800

Delta Tributaries—								
Littlejohns Creek	41	3,200	1,900	8,100	5,900	5,300	5,300	4,500
Martells Creek Group	122	5,200	2,000	14,300	10,400	9,300	9,200	7,800
Calaveras River	394	66,500	13,400	218,000	177,000	121,000	108,000	86,500
Mokelumne River	632	462,900	208,500	828,000	691,000	575,000	559,000	510,000
Sutter Creek Group	285	36,600	8,700	94,000	70,800	65,000	65,500	52,500
Cosumnes River	534	165,000	45,900	393,000	324,000	256,000	253,000	219,000
Totals, Delta tributaries	2,008	739,400	280,400	1,555,400	1,279,100	1,031,600	1,000,000	880,300
Grand totals	18,178	5,702,700	2,902,400	11,615,200	9,628,400	7,846,700	7,583,200	6,673,300

Table D-3 gives a summary of the means of the full natural run-offs of the streams of the San Joaquin River Basin tributary to the upper San Joaquin Valley, the lower San Joaquin Valley and the delta for each of the periods used in Table D-2. For purposes of comparison, the corresponding data are given in the table for various periods discussed in Chapter II, which do not include the seasons of 1929–30 and 1930–31.

TABLE D-3

SUMMARY OF MEAN SEASONAL FULL NATURAL RUN-OFF OF SAN JOAQUIN RIVER BASIN STREAMS FOR VARIOUS PERIODS

In Acre-feet

Period	Upper San Joaquin Basin	Lower San Joaquin Basin	Delta tributaries	Totals
1889–1929	5,646,200	4,725,900	1,607,900	11,980,000
1889–1931	5,470,500	4,589,300	1,555,400	11,615,200
1909–1929	4,827,300	3,976,400	1,355,900	10,159,600
1909–1931	4,567,900	3,781,400	1,279,100	9,628,400
1919–1929	3,932,400	3,475,900	1,138,600	8,546,900
1921–1931	3,476,200	3,107,000	1,000,000	7,583,200
1924–1929	3,688,700	3,345,500	1,102,800	8,137,000
1926–1931	3,059,200	2,733,800	880,300	6,673,300

Ultimate Net Run-offs—The ultimate net run-offs for the seasons 1929–30 and 1930–31 of the major streams at the reservoir sites of the State Water Plan are shown in Table D-4. These ultimate net run-offs are those that could have been expected under conditions of ultimate impairment by diversions for ultimate irrigation developments and present power developments, upstream from each reservoir site. Mean values for various periods also are set forth in the tabulation.

TABLE D-4

ULTIMATE NET SEASONAL RUN-OFF OF MAJOR STREAMS AT RESERVOIR SITES OF STATE PLAN IN SAN JOAQUIN RIVER BASIN

Stream	Run-off, in acre-feet		Mean run-off for period, in acre-feet				
	1929–1930	1930–1931	1889–1931	1909–1931	1917–1931	1921–1931	1926–1931
Kern River	346,700	184,100	692,000	642,000	465,000	435,000	399,000
Tule River[1]	46,400	17,600	126,000	102,000	73,800	70,300	60,000
Kaweah River	217,600	114,200	430,000	338,000	283,000	271,000	248,000
Kings River	862,800	465,800	1,830,000	1,497,000	1,222,000	1,161,000	1,027,000
San Joaquin River	868,600	562,800	1,932,000	1,613,000	1,308,000	1,254,000	1,083,000
Fresno River	20,600	7,100	53,200	45,100	35,800	34,500	27,600
Chowchilla River	31,700	3,000	68,300	52,600	48,900	49,400	38,700
Merced River	413,400	186,900	957,000	778,000	638,000	618,000	519,000
Tuolumne River	1,079,800	579,800	1,596,000	1,342,000	1,168,000	1,135,000	1,081,000
Stanislaus River	611,700	221,000	1,200,000	944,000	758,000	745,000	663,000
Calaveras River	45,000	13,100	182,000	144,000	91,100	79,600	61,600
Mokelumne River	383,400	216,900	795,000	660,000	547,000	532,000	481,000
Cosumnes River	84,400	25,400	279,000	219,000	159,000	161,000	131,000
Totals	5,012,100	2,597,700	10,140,500	8,376,700	6,797,600	6,545,800	5,819,900

[1] Includes South Fork of Tule River, which enters the main Tule River below the reservoir site of the State Plan.

Adequacy of Initial Units of State Water Plan.

In Chapter VIII, the operation and accomplishments of the initial units of the State Water Plan in the San Joaquin River Basin are described. The analyses on which the accomplishments for both the immediate and complete initial developments were based covered the 12-year period 1917–1929. In testing the adequacy of these units, studies were made covering the seasons of 1929–30 and 1930–31.

Immediate Initial Development—Analyses presented in Chapter VIII, based on water supply studies for the 12-year period 1917–1929 and on water supply and ground water studies for the 8-year period 1921–1929, demonstrated that sufficient water to meet the needs of present developed areas in the upper San Joaquin Valley, having a permanent deficiency in water supply, could have been most economically secured by the utilization of surplus water of the San Joaquin River and water available by purchase under rights devoted to inferior use on "grass lands" for pasture, now being served by diversions from this river above the mouth of the Merced River. The physical works of the immediate initial State Water Plan in the San Joaquin River Basin required for the utilization of these supplies are Friant Reservoir, Madera Canal and San Joaquin River-Kern County Canal. Analyses have been made, by extending the water supply and accumulative ground water studies through the seasons of 1929–30 and 1930–31, to demonstrate to what degree the plan adopted for immediate initial development would have met the needs of present developed areas of permanent deficiency in those seasons.

Table D-5 sets forth the measured monthly run-off of the major streams in upper San Joaquin Valley for the seasons of 1929–30 and 1930–31. Table D-6 sets forth by months for the seasons of 1929–30 and 1930–31 the utilization of the total impaired run-off of the San Joaquin River at Friant under conditions of immediate initial development, with the quantities and characteristics of supply for the Madera Canal and the San Joaquin River-Kern County Canal; and the corresponding average values for the 14-year period 1917–1931, 10-year period 1921–1931, and 5-year period 1926–1931. The bases of operation of the reservoir and the allocation of supplemental supplies therefrom are the same as set forth in Chapter VIII.

Table D-7 sets forth, for each season of the 10-year period 1921–1931, the water supply from Friant Reservoir, from local sources and from the combined sources that would have been available for units in the upper San Joaquin Valley receiving imported supplemental water under the plan of immediate initial development; and the net accretion to or depletion of ground water storage in the absorptive areas during this 10-year period which would have resulted from the furnishing of this water supply, after fully satisfying assumed water requirements based upon the net areas irrigated in 1929. An inspection of the tabulation reveals that the nonabsorptive areas consisting of the Alta-Foothill, Lindsay and Magunden-Edison units would have received a full surface supply in all seasons except 1930–31 when the Alta-Foothill unit would have had a deficiency of 20 per cent, the Lindsay unit, 10 per cent and the Magunden-Edison unit, 15 per cent. In both seasons 1929–30 and 1930–31, none of the absorptive areas except

TABLE D-5

MEASURED MONTHLY RUN-OFF OF MAJOR STREAMS IN UPPER SAN JOAQUIN VALLEY FOR THE SEASON OF 1929-30 AND 1930-31

Stream	Location of gaging station	Run-off, in acre-feet												
		October	November	December	January	February	March	April	May	June	July	August	September	Totals
Season 1929-30—														
Kern River	Near Bakersfield	8,800	9,000	10,000	12,200	20,100	34,600	53,500	67,800	82,800	28,400	11,800	7,700	346,700
Tule River*	Near Porterville	100	200	700	2,200	4,700	11,400	9,400	12,800	4,300	400	100	100	46,400
Kaweah River	Near Three Rivers	1,600	1,600	2,200	5,400	12,900	23,200	45,000	64,000	50,500	7,800	2,100	1,300	217,600
Kings River	At Piedra	7,200	6,700	8,300	15,000	31,600	71,900	171,000	231,000	241,000	55,000	16,500	7,600	862,800
San Joaquin River	Near Friant	29,800	24,900	31,600	30,300	39,200	70,700	121,000	138,000	155,000	96,500	79,900	51,700	868,600
Fresno River	Near Knowles	0	0	100	2,100	3,000	6,200	3,300	3,000	1,800	200	0	0	19,700
Chowchilla River**	At Buchanan	0	300	500	3,600	5,400	10,800	5,000	3,200	2,600	300	0	0	31,700
Season 1931-31—														
Kern River	Near Bakersfield	9,300	11,100	10,600	12,300	13,800	15,800	23,400	41,900	24,300	8,500	6,300	6,800	184,100
Tule River*	Near Porterville	0	1,300	1,700	3,400	3,100	3,000	2,800	2,100	200	0	0	0	17,600
Kaweah River	Near Three Rivers	1,400	3,700	3,100	5,800	7,300	11,300	23,600	40,600	12,600	2,400	1,300	1,100	114,200
Kings River	At Piedra	8,600	11,800	9,000	12,600	17,500	30,900	98,200	184,000	58,700	14,300	10,100	10,100	465,800
San Joaquin River	Near Friant	42,900	32,600	26,900	33,700	29,900	41,300	92,200	107,000	55,400	52,900	38,700	9,300	562,800
Fresno River	Near Knowles	0	600	300	800	1,200	700	1,100	1,100	300	0	0	0	6,100
Chowchilla River	At Buchanan	0	0	100	900	1,000	700	200	100	0	0	0	0	3,000

*Includes run-off of South Fork near Success.
**Estimated from index of seasonal wetness.

TABLE D-6

SEASONAL UTILIZATION OF THE IMPAIRED RUN-OFF OF THE SAN JOAQUIN RIVER AT FRIANT UNDER CONDITIONS OF IMMEDIATE INITIAL DEVELOPMENT, IN ACRE-FEET

Period	Prior crop land rights	Diversions for Upper San Joaquin Valley							Reservoir evaporation loss	Waste past reservoir	Net contribution to reservoir storage	Total impaired run-off
		Madera Canal			San Joaquin River-Kern County Canal			Totals				
		In-season	Out-of-season	Totals	In-season	Out-of-season	Totals					
1929-1930—												
October	27,900	400	0	400	4,400	0	4,400	4,800	800	0	—3,700	29,800
November	8,400	0	0	0	1,100	0	1,100	1,100	600	0	+14,800	24,900
December	6,400	0	0	0	1,100	0	1,100	1,100	0	0	+24,100	31,600
January	10,000	0	0	0	2,200	0	2,200	2,200	0	0	+18,100	30,300
February	27,900	300	0	300	3,300	0	3,300	3,600	0	0	+7,700	39,200
March	51,600	2,200	0	2,200	7,500	0	7,500	9,700	0	0	+9,400	70,700
April	114,700	5,300	0	5,300	11,500	0	11,500	16,800	1,000	0	—11,500	121,000
May	138,000	7,300	0	7,300	14,600	0	14,600	21,900	1,400	0	—23,300	138,000
June	155,000	6,700	0	6,700	16,900	0	16,900	23,600	1,500	0	—25,100	155,000
July	96,500	4,200	0	4,200	8,400	0	8,400	12,600	1,600	0	—14,200	96,500
August	79,900	0	0	0	0	0	0	0	1,400	0	—1,400	79,900
September	51,700	0	0	0	0	0	0	0	1,100	0	—1,100	51,700
Totals for season 1929–30	768,000	26,400	0	26,400	71,000	0	71,000	97,400	9,400	0	—6,200	868,600
1930-1931—												
October	27,900	400	0	400	5,500	0	5,500	5,900	800	0	+8,300	42,900
November	8,400	0	0	0	1,100	0	1,100	1,100	600	0	+22,500	32,600
December	6,400	0	0	0	1,100	0	1,100	1,100	0	0	+19,400	26,900
January	10,000	0	0	0	2,200	0	2,200	2,200	0	0	+21,500	33,700
February	27,900	300	0	300	3,300	0	3,300	3,600	0	0	—1,600	29,900
March	41,300	2,200	0	2,200	7,500	0	7,500	9,700	0	0	—9,700	41,300
April	92,200	5,300	0	5,300	11,500	0	11,500	16,800	1,000	0	—17,800	92,200
May	107,000	7,300	0	7,300	14,600	0	14,600	21,900	1,300	0	—23,200	107,000
June	55,400	6,700	0	6,700	8,800	0	8,800	15,500	1,400	0	—16,900	55,400
July	52,900	0	0	0	0	0	0	0	1,500	0	—1,500	52,900
August	38,700	0	0	0	0	0	0	0	1,400	0	—1,400	38,700
September	9,300	0	0	0	0	0	0	0	1,100	0	—1,100	9,300
Totals for season 1930–31	477,400	22,200	0	22,200	55,600	0	55,600	77,800	9,100	0	—1,500	562,800
Mean seasonal, 1917–31	769,800	87,300	8,100	95,400	337,300	95,900	433,200	528,600	10,800	2,700	—800	1,311,100
Mean seasonal, 1921–31	747,000	79,400	11,400	90,800	311,200	96,100	407,300	498,100	10,700	3,800	—1,100	1,258,500
Mean seasonal, 1926–31	726,400	60,500	0	60,500	229,400	68,200	297,600	358,100	10,300	0	—2,200	1,092,600

Madera would have received any water from Friant Reservoir. However, the total supply for all absorptive areas, for the 10-year period, would have exceeded net use requirements by 20,000 acre-feet. Although ground water storage would be depleted at the end of the 10-year period in certain units, the total accretions in other units exceed the total amounts of depletion. With minor changes in allotment, in certain seasons, all ground water reservoirs would have finished the 10-year period with slightly higher water levels at the end than at the beginning, after having furnished a full supply every season equal to the requirements for the areas irrigated in 1929.

With the water supply available during the 10-year period 1921–31 and with water requirements based upon the area irrigated in 1929 assumed to be furnished throughout the period, the weighted average pumping lifts for all absorptive areas would have been nearly as great in 1930–31 as in 1921–22. Assuming that the operation of the plan of immediate initial development were started in 1931 and the water supply for the 10-year period 1931–1941 were equal to that of the 10-year period 1921–1931, practically the same conditions of ground water depletion and excessive pumping lifts would exist at the end of 1941 as under present conditions. However, should the period following the completion of the plan of immediate initial development more closely approach the normal, the available water supply for utilization would replenish the underground reservoirs in addition to fully meeting the requirements of present areas of deficiency.

It was pointed out in Chapter VIII that, should the run-off occurring in future years result in a succession of seasons more subnormal than experienced during the period 1917–1929 upon which the water supply studies for immediate initial development are based, the utilizable water supply, from both local and supplemental sources, which would be available under the proposed plan of immediate intial development might be materially less than estimated for the period 1917–1929; and that, in this event, additional supplemental supplies might be required to adequately meet the needs of present developed areas. Adequate relief should include not only the furnishing of supplies to offset present deficiencies between supply and actual net use requirements, but also substantial ground water replenishment to reduce present excessive pumping lifts. The only dependable and practicable source of additional supplemental water supply would be the Sacramento River Basin, and the San Joaquin River Pumping System would be required to import supplies from this source to be used in the San Joaquin Valley. It was concluded in a previous report* that the construction of this unit might be deferred until experience demonstrated the need of additional water for initial development, but that provision should be made in the plan of financing for funds to construct this unit so that adequate relief would be assured for the present developed areas of deficient water supply. The foregoing studies extending the analyses of water supply under the plan of immediate initial development to include the seasons of 1929–30 and 1930–31 have further demonstrated the desirability of the inclusion of the San

*Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930. (See pages 45 and 160.)

SEASJIRING AN IMPORTED SUPPLY IN UPPER SAN JOAQUIN
RRIGATED AREAS AS OF 1929

	-31	Mean for period, 1921-1931	Net area irrigated in 1929, in acres	Estimated seasonal net use requirements: Acre-feet per acre[2]	Estimated seasonal net use requirements: Acre-feet	Total net accretion (+) to or depletion (—) of ground water storage during 10-year period, 1921-1931, in acre-feet
Mader	2,500	95,880				
	2,200	90,820				
	4,700	186,700	81,000	2.5	202,500	—158,000
Lower	0	28,010	------------	------------	------------	------------
Alta-I	5,600	33,830	16,000	2.0	32,000	------------
Kawe	0,000	229,610				
	0	82,480				
	0,000	312,090	[1]122,900	2.5	307,300	+47,900
Linds	4,200	14,130				
	5,600	33,830				
	9,800	47,960	22,000	2.0	44,000	------------
Tule-	2,700	81,580				
	0	64,030				
	2,700	145,610	[4]75,200	2.2	165,400	—197,900
Earli	800	2,450				
	0	83,270				
	800	85,720	30,500	2.0	61,000	+247,200
McFa	0	31,620				
	0	76,060				
	0	107,680	49,800	2.0	99,600	+80,800
Magu	4,400	5,800	2,600	2.0	5,200	------------
T	50,200	455,270				
	77,800	498,130				
	28,000	953,400	400,000	------------	917,000	+20,000

1
2
3
4

809

Madera would have received any water from Friant Reservoir. However, the total supply for all absorptive areas, for the 10-year period, would have exceeded net use requirements by 20,000 acre-feet. Although ground water storage would be depleted at the end of the 10-year period in certain units, the total accretions in other units exceed the total amounts of depletion. With minor changes in allotment, in certain seasons, all ground water reservoirs would have finished the 10-year period with slightly higher water levels at the end than at the beginning, after having furnished a full supply every season equal to the requirements for the areas irrigated in 1929.

With the water supply available during the 10-year period 1921–31 and with water requirements based upon the area irrigated in 1929 assumed to be furnished throughout the period, the weighted average pumping lifts for all absorptive areas would have been nearly as great in 1930–31 as in 1921–22. Assuming that the operation of the plan of immediate initial development were started in 1931 and the water supply for the 10-year period 1931–1941 were equal to that of the 10-year period 1921–1931, practically the same conditions of ground water depletion and excessive pumping lifts would exist at the end of 1941 as under present conditions. However, should the period following the completion of the plan of immediate initial development more closely approach the normal, the available water supply for utilization would replenish the underground reservoirs in addition to fully meeting the requirements of present areas of deficiency.

It was pointed out in Chapter VIII that, should the run-off occurring in future years result in a succession of seasons more subnormal than experienced during the period 1917–1929 upon which the water supply studies for immediate initial development are based, the utilizable water supply, from both local and supplemental sources, which would be available under the proposed plan of immediate intial development might be materially less than estimated for the period 1917–1929; and that, in this event, additional supplemental supplies might be required to adequately meet the needs of present developed areas. Adequate relief should include not only the furnishing of supplies to offset present deficiencies between supply and actual net use requirements, but also substantial ground water replenishment to reduce present excessive pumping lifts. The only dependable and practicable source of additional supplemental water supply would be the Sacramento River Basin, and the San Joaquin River Pumping System would be required to import supplies from this source to be used in the San Joaquin Valley. It was concluded in a previous report* that the construction of this unit might be deferred until experience demonstrated the need of additional water for initial development, but that provision should be made in the plan of financing for funds to construct this unit so that adequate relief would be assured for the present developed areas of deficient water supply. The foregoing studies extending the analyses of water supply under the plan of immediate initial development to include the seasons of 1929–30 and 1930–31 have further demonstrated the desirability of the inclusion of the San

*Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930. (See pages 45 and 160.)

TABLE D-7

SEASONAL WATER SUPPLY AND NET ACCRETION TO OR DEPLETION OF GROUND WATER STORAGE DURING PERIOD 1921-1931 FOR AREAS REQUIRING AN IMPORTED SUPPLY IN UPPER SAN JOAQUIN VALLEY UNDER CONDITIONS OF IMMEDIATE INITIAL DEVELOPMENT, WITH WATER REQUIREMENTS BASED UPON IRRIGATED AREAS AS OF 1929

Unit or area	Source of water supply	Seasonal surface water supply, in acre-feet											Net area irrigated in 1929, in acres	Estimated seasonal net use requirements		Total net accretion (+) to or depletion (—) of ground water storage during 10-year period, 1921-1931, in acre-feet
		1921-22	1922-23	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29	1929-30	1930-31	Mean for period, 1921-1931		Acre-feet per acre[2]	Acre-feet	
Madera	Local	205,100	154,800	24,000	134,800	66,700	143,600	100,300	62,100	55,100	12,500	95,880				
	Friant Reservoir	245,800	132,100	32,700	104,900	90,500	130,400	90,500	32,700	26,400	22,200	90,820				
	Totals	450,900	286,900	56,700	230,500	157,200	274,000	190,800	94,800	81,500	34,700	188,700	81,000	2.5	202,600	—158,000
Lower Kings River	Friant Reservoir	85,200	48,400	6,200	18,500	26,700	60,200	26,200	2,700	0	0	28,010	----------	----------	----------	----------
Alta-Foothill	Friant Reservoir	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000	32,700	25,600	33,830	16,000	2.0	32,000	----------
Kaweah	Local	377,300	299,700	88,000	274,200	185,000	405,200	182,100	194,800	189,800	100,000	229,610				
	Friant Reservoir	250,900	142,700	18,200	54,500	78,500	194,900	77,200	7,900	0	0	82,480				
	Totals	628,200	442,400	106,200	328,700	263,500	600,100	259,300	202,700	189,800	100,000	312,090	[1]122,900	2.5	307,300	+47,900
Lindsay	Local[3]	13,400	14,100	13,700	12,700	14,100	13,300	14,300	15,500	16,000	14,200	14,130				
	Friant Reservoir	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000	32,700	25,600	33,830				
	Totals	48,400	49,100	48,700	47,700	49,100	48,300	49,300	50,500	48,700	39,800	47,960	22,000	2.0	44,000	----------
Tule-Deer Creek	Local	158,600	116,400	29,600	107,400	56,500	146,600	57,100	88,200	54,700	22,700	81,580				
	Friant Reservoir	194,800	110,800	14,100	42,300	60,900	151,300	60,000	6,100	0	0	64,030				
	Totals	351,400	227,200	4[illegible],700	149,700	117,400	297,900	117,100	74,300	54,700	22,700	145,610	[4]75,200	2.2	165,400	—197,900
Earlimart-Delano	Local	3,700	4,800	0	3,600	1,400	4,700	2,300	1,900	1,300	800	2,450				
	Friant Reservoir	253,300	144,100	18,300	55,000	79,200	196,800	78,000	8,000	0	0	83,270				
	Totals	257,000	148,900	18,300	58,600	80,600	201,500	80,300	9,900	1,300	800	85,720	30,500	2.0	61,000	+247,200
McFarland-Shafter	Local	123,100	52,500	0	23,400	13,600	82,000	11,800	4,800	6,000	0	31,620				
	Friant Reservoir	231,300	131,600	16,800	50,300	72,400	179,700	71,200	7,300	0	0	76,060				
	Totals	354,400	184,100	16,800	73,700	86,000	261,700	83,000	12,100	6,000	0	107,680	49,800	2.0	99,600	+80,800
Magunden-Edison	Friant Reservoir	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	5,600	4,400	5,800	2,600	2.0	5,200	----------
Totals	Local	879,200	642,300	155,300	555,900	337,300	795,400	367,900	347,300	321,900	150,200	455,270				
	Friant Reservoir	1,337,300	785,700	182,300	401,500	484,200	995,300	479,100	140,700	97,400	77,800	498,130				
	Totals	2,216,500	1,428,000	337,600	957,400	821,500	1,790,700	847,000	488,000	419,300	228,000	953,400	400,000	----------	917,000	+20,000

[1] Excludes 5,600 acres of irrigated pasture.
[2] On basis of per acre values determined in Chapter IV.
[3] Importation from Kaweah River in accord with diversions of Lindsay-Strathmore Irrigation District. Amounts diverted to Lindsay Unit deducted from local supply of Kaweah Unit.
[4] Includes 5,000 acres east of ground water unit.

Joaquin River Pumping System as an initial unit in the financing of the plan.

Complete Initial Development—With the units of the plan of complete initial development constructed and in operation, practically the entire flow of the San Joaquin River at Friant would be available for diversion into the upper San Joaquin Valley. The average seasonal yield from the Friant Reservoir for the 14-year period 1917–1931 would have been 1,272,000 acre-feet. The average seasonal utilizable yield from the Chowchilla, Fresno, Kings, Kaweah, Tule and Kern rivers, for this period, was about 2,058,000 acre-feet. The average combined total yield of 3,330,000 acre-feet would have satisfied the requirements of 1,665,000 acres or about one and one-half times the irrigated area now receiving a supply from these streams.

The San Joaquin River Pumping System would make available water supplies from the delta and the lower San Joaquin River tributaries, for "crop lands" now being served from the San Joaquin River. These crop lands would have received a full supply in all seasons except 1930–31. In that season there would have been a deficiency of 35 per cent through the months of May to September, inclusive. The deficiency for the entire season would have been 25 per cent. Even with this deficiency, the amount received would have exceeded the amount actually available to these lands during the season 1930–31 by 191,000 acre-feet or 40 per cent more water. The monthly contributions of surplus and return waters from the lower San Joaquin Valley for the seasons 1929–30 and 1930–31 are set forth in Table D-8. The means for the 14-year period 1917–31 are also shown. This table is an extension of Table 183 in Chapter VIII, and the bases of compilation and explanation of the quantities are the same as set forth in that chapter. The deficiencies shown would be supplied by pumping Sacramento River water from the delta and would have been fully met from this source except during the months of May to September, inclusive, in 1931 when there would have been a deficiency of 35 per cent.

Adequacy of Major Units of Ultimate State Water Plan.

The operation and accomplishments of the major units of the ultimate State Water Plan in the San Joaquin River Basin and in the entire Great Central Valley, based upon the 40-year period of run-off 1889–1929, are presented in Chapter VII. In the analyses shown therein of the water supply that would have been made available by the proposed units of the ultimate plan during the 40-year period 1889–1929, it was demonstrated that the irrigable areas to be served under ultimate development in practically all of the lower San Joaquin Valley and along the west side of the upper San Joaquin Valley would have received an adequate surface supply of water obtained through surface storage regulation on local streams and from importations from the Sacramento River Basin, with a maximum deficiency of not to exceed 35 per cent in any season during that period; and that the eastern and southern slopes of the upper San Joaquin Valley would have received a full supply without deficiency through the combined utilization of surface and underground storage. No utilization was

TABLE D-8

UTILIZATION OF RETURN FLOW AND UNREGULATED SURPLUS WATERS IN LOWER SAN JOAQUIN RIVER UNDER EXISTING IRRIGATION AND STORAGE CONDITIONS AND MUNICIPAL DIVERSIONS AS OF 1940 TO SUPPLY LOWER SAN JOAQUIN VALLEY CROP LANDS

Season	Item	Quantities, in acre-feet												
		October	November	December	January	February	March	April	May	June	July	August	September	Totals
	Demand of Lower San Joaquin Valley crop lands	27,900	8,400	6,400	10,000	27,900	51,600	114,700	158,700	163,000	142,000	108,300	76,800	895,700
1929-30	Inflow to delta[1]	31,500	34,200	42,000	92,600	95,300	136,100	192,800	178,500	160,900	33,100	29,500	34,200	1,060,700
	Excess	3,600	25,800	35,600	82,600	67,400	84,500	78,100	19,800					397,400
	Deficiency									2,100	108,900	78,800	42,600	232,400
1930-31	Inflow to delta[1]	33,200	51,100	66,500	68,700	67,800	37,200	19,700	1,500	14,200	16,000	13,000	17,700	406,600
	Excess	5,300	42,700	60,100	58,700	39,900								206,700
	Deficiency						14,400	95,000	101,600	91,700	76,300	57,400	32,100	468,500
Mean, 1917-1931	Inflow to delta[1]	65,600	80,100	97,800	121,100	170,100	215,200	318,300	499,900	374,000	88,900	40,700	44,900	2,116,600
	Excess	37,700	71,700	91,400	111,100	142,200	165,000	216,200	360,500	246,300	19,300			1,461,400
	Deficiency						1,500	12,600	15,300	31,200	68,900	64,900	30,000	224,400

[1] Quantities shown for inflow to the delta are the estimated amounts of surplus and return flow waters as measured immediately above Dam No. 1 of the San Joaquin River Pumping System. They comprise the estimated flow of the San Joaquin River above Merced River, adjusted for the operation of Friant Reservoir and diversions through the Madera and San Joaquin River-Kern County canals and for greater return flow due to increased supply to the lower San Joaquin Valley "crop lands" under the plan of complete initial development; and the estimated flow of the Merced, Tuolumne, and Stanislaus rivers at their junction with the San Joaquin River under existing irrigation and storage conditions and municipal diversions as of 1940, with deductions for west-side pumping diversions from Patterson Colony to Banta-Carbona Irrigation District, inclusive.

made of the available capacity of underground reservoirs in the lower San Joaquin Valley for storage regulation and subsequent extraction by pumping, except to a minor extent in Hydrographic Division No. 8. In order to test the adequacy of the proposed ultimate plan of development through the dry seasons of 1929–30 and 1930–31, the analyses of water supply and the studies of the operation of the major surface storage and conveyance units and the underground reservoirs were extended through these two additional seasons. In making this test the same methods were employed for estimating the available surface water supplies as were used and described in Chapter VII, with studies of water supply made on a month by month basis.

Utilizable Yield of Surface Water Supplies in the Seasons 1929–30 and 1930–31—The utilizable yields of surface water supplies which would have been available in the seasons of 1929–30 and 1930–31 under the ultimate State Water Plan in the San Joaquin River Basin are set forth in Table D-9. The table shows for each season the yield from the major streams in the San Joaquin River Basin, the contributions from minor streams in the upper San Joaquin Valley, the return flow and unregulated surplus water from the lower San Joaquin Valley and the water supply that would be imported from the Sacramento River Basin.

TABLE D-9

UTILIZABLE YIELD OF SURFACE WATER SUPPLIES FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN IN SEASONS 1929-30 AND 1930-31

Source	Surface reservoir	Capacity of reservoir in acre-feet	Total seasonal yield in acre-feet	
			1929-1930	1930-1931
Kern River	Isabella	338,000	346,700	184,100
Tule River	Pleasant Valley	39,000	44,700	17,600
Kaweah River			217,600	114,200
Kings River	Pine Flat	400,000	862,800	465,800
San Joaquin River	Friant	(Net)270,000	860,000	554,200
Fresno River	Windy Gap	62,000	20,300	7,100
Chowchilla River	Buchanan	84,000	30,900	3,000
Merced River	Exchequer	279,000	409,000	185,900
Tuolumne River	Don Pedro	1,000,000	1,072,500	577,800
Stanislaus River	Melones	1,090,000	607,400	220,700
Calaveras River	Valley Springs	325,000	43,000	12,200
Mokelumne River	Pardee	222,000	156,800	78,000
Dry Creek	Ione	610,000	23,500	7,800
Cosumnes River	Nashville	281,000	137,400	24,200
Return flow and unregulated surplus water from lower San Joaquin Valley			1,042,000	777,000
Minor streams, upper San Joaquin Valley			57,400	54,400
From Sacramento River Basin			2,791,000	1,728,000
Totals			8,723,000	5,012,000

The total seasonal yields available from surface supplies to meet the needs of the San Joaquin Valley and adjacent foothill areas below the major reservoirs, under the plan of ultimate development, as shown by the foregoing tabulation, would have been 8,723,000 acre-feet in 1929–1930 and 5,012,000 acre-feet in 1930–1931 for a total area of 4,945,000 acres having a total seasonal water requirement (gross allowance) of 11,612,000 acre-feet. The available surface supply for the season of 1930–1931 would have been but 43 per cent of the gross requirement.

Under the plan of operation set forth in Chapter VII for ultimate development, the utilizable yield of surface water supplies in the seasons 1929–30 and 1930–31, with these two dry seasons following a period of generally subnormal supply extending from 1917 to 1929, are so small in amount that there would have been insufficient water in certain areas to meet the requirements. Carry over storage in the surface reservoirs and ground water supplies in certain of the underground reservoirs of the upper San Joaquin Valley south of the San Joaquin River would have been exhausted to such an extent that large deficiencies would have occurred in the season 1930–31.

Modified Plan of Operation for Ultimate State Water Plan in San Joaquin River Basin—In order to provide adequate supplies in the season 1930–31 for all areas in the San Joaquin River Basin, it was found necessary to modify the plan of operation as set forth in Chapter VII so as to make greater utilization of the underground reservoirs not only in the upper San Joaquin Valley but also in certain areas of the lower San Joaquin Valley.

An equal degree of utilization of all ground water reservoirs in the upper San Joaquin Valley would be required to eliminate the deficiencies which would have occurred in Hydrographic Divisions 1, 2 and 3 in 1930–31 under the plan of operation set forth in Chapter VII. Under the modified plan of operation, greater utilization would be made of the underground reservoir in Hydrographic Division No. 6 and a smaller amount of surface irrigation supply from Friant Reservoir would be allocated to this area in order to make more water available from this reservoir to the areas south of the San Joaquin River.

In the lower San Joaquin Valley, under the modified plan of operation, the underground reservoirs would be utilized for obtaining ground water supplies to supplement the available surface water supplies in the seasons of 1929–30 and 1930–31 in Hydrographic Divisions 8, 9 and 11, and in the season of 1930–31 in Hydrographic Division No. 12. In addition to utilization of ground water supplies to meet the water requirements in these hydrographic divisions in these seasons, it was found that additional water would be required in the season 1930–31 for Hydrographic Division No. 11 in order to meet a large deficiency which would have occurred in that season in this division. The additional supply required could have been furnished by importation from the American River. Hence, the modified plan of operation would provide for serving a portion of the water requirements in Hydrographic Division No. 11 with American River water. In any normal or greater than normal season there would be a surplus of 68,000 acre-feet over and above the requirements for Hydrographic Divisions 12 and 13, in the supply available from the American River which could be allocated to Hydrographic Division No. 11. This would reduce the drafts required from Melones Reservoir by an equal amount and would permit the accumulation of storage in the reservoir to hold over for use during periods of subnormal supply. A monthly analysis under this modified plan of operation for Hydrographic Division No. 11 under conditions of ultimate development showed that there would be only a small deficiency in 1930–31. The supplies from the American River for Hydrographic Divisions 12 and 13 would not be reduced under this modified plan of operation except in the season 1930–31 when the studies showed that it would have been necessary to allocate all available American River water to Hydrographic Divisions 11 and 13 with none allocated to Hydrographic Division No. 12 in that season. This would have necessitated the utilization of ground water in Hydrographic Division No. 12 in order to obtain an adequate supply for this area during the season 1930–31.

Results of Modified Plan of Operation in Upper San Joaquin Valley—Under the plan of operation set forth in Chapter VII, the underground reservoirs in Hydrographic divisions 1, 2, 3, 4 and 6 would have been full in 1917. Therefore, in the consideration of a modified plan of operation as regards particularly the allocation of the supplies made available from Friant Reservoir to the hydrographic divisions in the upper San Joaquin Valley, the 14-year period 1917–1931 was analyzed. Numerous trial studies were required to determine the proper allocation of San Joaquin River water from Friant Reservoir in order to provide adequate supplies for all hydrographic divisions on the east side of the upper San Joaquin Valley and prevent depletion of the underground reservoirs in Hydrographic Divisions 1, 2 and 3 which would have occurred under the plan of operation set forth in Chapter VII.

Under the modified plan of operation that was found to meet the requirements during the 14-year period including the season 1930–31, Hydrographic Division No. 6 would receive through the Madera Canal 10 per cent of the water available for diversion at Friant Reservoir, except during May and June in seasons of greater than normal run-off and during periods when Friant Reservoir would be spilling when it would be served additional water for ground water recharge limited by the 1500 second-feet diversion capacity of the Madera Canal. Division 1 would receive 29 per cent; Division 2, 56 per cent; and Division 3, 5 per cent of the total water available for diversion at Friant Reservoir limited by the 3000 second-feet diversion capacity of the San Joaquin River-Kern County Canal. Local supplies in Hydrographic Division No. 4 were found to be sufficient through 1930–31 and hence no allocation of San Joaquin River water was made for that area. Table D-10 sets forth the allocation of the yield from the Friant Reservoir during the 14-year period 1917–1931, by hydrographic divisions, without and with modification of the plan of operation under ultimate development.

Under the modified plan of operation with the change in allocation of water supplies from Friant Reservoir, seasonal analyses were made of the accumulative ground water storage in the absorptive areas of each of these hydrographic divisions for the 14-year period 1917–31, using methods and limiting factors of utilizable yield similar to those presented in Chapter VII in the original accumulative ground water analyses. Studies show that the maximum capacity of water supply utilization in Hydrographic Division No. 6 is materially in excess of the water supplies made available under the modified plan of operation during the 14-year period considered. During periods when the underground reservoirs would have been nearly full or the surface supplies would have closely approached the maximum capacity of utilization, the analyses were made month by month. The results of these analyses are presented in Table D-11 which sets forth by seasons, for each hydrographic division, the utilizable local and imported water supplies, net use requirement, seasonal net contributions to or extractions from ground water and the water supply remaining in ground water storage at the end of each season for the 14-year period 1917–1931.

TABLE D-10

ALLOCATION OF TOTAL YIELD FROM FRIANT RESERVOIR UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

For 14-year Period 1917-1931

Hydrographic division	Allocation of yield, without modification of plan		Allocation of yield, with modification of plan	
	Acre-feet	Per cent of total	Acre-feet	Per cent of total
1	4,098,000	23.0	5,064,200	28.5
2	8,460,400	47.5	*9,779,400	54.9
3	661,000	3.7	873,300	4.9
6	4,586,400	25.8	**2,088,500	11.7
Totals	17,805,800	100.0	17,805,400	100.0

* 7,900 acre-feet occurring in season 1917-18 not utilizable.
** 4,500 acre-feet occurring in season 1917-18 not utilizable.

TABLE D-11

SEASONAL WATER SUPPLY, WATER REQUIREMENTS, CONTRIBUTIONS TO GROUND WATER AND WATER SUPPLY REMAINING IN STORAGE AT END OF EACH SEASON IN UNDERGROUND RESERVOIRS, IN ABSORPTIVE AREAS OF UPPER SAN JOAQUIN VALLEY UNDER MODIFIED PLAN OF OPERATION FOR ULTIMATE DEVELOPMENT DURING PERIOD 1917-1931

(Quantities, in Acre-feet)

Season	Utilizable local water supply	Utilizable imported water supply	Total utilizable water supply	Net use	Seasonal net contribution (+) to or extraction (—) from ground water	Water supply remaining in ground water storage
Hydrographic Division 1						
1916-17	----------	----------	----------	----------	----------	3,750,000
1917-18	606,000	445,000	1,051,000	1,058,000	—7,000	3,743,000
1918-19	606,000	389,500	995,500	1,058,000	—62,500	3,680,500
1919-20	606,000	376,800	982,800	1,058,000	—75,200	3,605,300
1920-21	531,300	449,200	980,500	1,058,000	—77,500	3,527,800
1921-22	583,700	482,200	1,065,900	1,058,000	+7,900	3,535,700
1922-23	606,000	497,400	1,103,400	1,058,000	+45,400	3,581,100
1923-24	323,600	184,600	508,200	1,058,000	—549,800	3,031,300
1924-25	463,600	368,600	832,200	1,058,000	—225,800	2,805,500
1925-26	340,100	355,300	695,400	1,058,000	—362,600	2,442,900
1926-27	584,100	502,000	1,086,100	1,058,000	+28,100	2,471,000
1927-28	521,400	351,200	872,600	1,058,000	—185,400	2,285,600
1928-29	328,500	252,300	580,800	1,058,000	—477,200	1,808,400
1929-30	346,700	249,400	596,100	1,058,000	—461,900	1,346,500
1930-31	184,100	160,700	344,800	1,058,000	—713,200	633,300
Totals	6,631,100	5,064,200	11,695,300	14,812,000	—3,116,700	
Average	473,700	361,700	835,400	1,058,000	—222,600	
Hydrographic Division 2						
1916-17	----------	----------	----------	----------	----------	3,650,000
1917-18	54,500	851,400	905,900	970,000	—64,100	3,585,900
1918-19	74,300	752,100	826,400	970,000	—143,600	3,442,300
1919-20	108,100	727,700	835,800	970,000	—134,200	3,308,100
1920-21	88,600	867,400	956,000	970,000	—14,000	3,294,100
1921-22	134,700	931,200	1,065,900	970,000	+95,900	3,390,000
1922-23	100,300	960,600	1,060,900	970,000	+90,900	3,480,900
1923-24	25,000	356,400	381,400	970,000	—588,600	2,892,300
1924-25	87,300	711,700	799,000	970,000	—171,000	2,721,300
1925-26	47,700	686,200	733,900	970,000	—236,100	2,485,200
1926-27	127,900	969,400	1,097,300	970,000	+127,300	2,612,500
1927-28	47,200	678,100	725,300	970,000	—244,700	2,367,800
1928-29	53,400	487,300	540,700	970,000	—429,300	1,938,500
1929-30	44,700	481,600	526,300	970,000	—443,700	1,494,800
1930-31	17,600	310,400	328,000	970,000	—642,000	852,800
Totals	1,011,300	9,771,500	10,782,800	13,580,000	—2,797,200	
Average	72,200	698,000	770,200	970,000	—199,800	
Hydrographic Division 3						
1916-17	----------	----------	----------	----------	----------	2,182,900
1917-18	229,700	76,700	306,400	498,000	—191,600	1,991,300
1918-19	289,200	67,200	356,400	498,000	—141,600	1,849,700
1919-20	372,100	65,000	437,100	498,000	—60,900	1,788,800
1920-21	360,800	77,500	438,300	498,000	—59,700	1,720,100
1921-22	461,100	83,200	544,300	498,000	+46,300	1,775,400
1922-23	363,500	85,800	449,300	498,000	—48,700	1,726,700
1923-24	101,700	31,800	133,500	498,000	—364,500	1,362,200
1924-25	325,500	63,500	389,000	498,000	—109,000	1,253,200
1925-26	218,800	61,300	280,100	498,000	—217,900	1,035,300
1926-27	483,200	86,600	569,800	498,000	+71,800	1,107,100
1927-28	203,000	60,500	263,500	498,000	—234,500	872,600
1928-29	222,800	43,500	266,300	498,000	—231,700	640,900
1929-30	217,600	43,000	260,600	498,000	—237,400	403,500
1930-31	114,200	27,700	141,900	498,000	—356,100	47,400
Totals	3,963,200	873,300	4,836,500	6,972,000	—2,135,500	
Average	283,100	62,400	345,500	498,000	—152,500	

TABLE D-11—Continued

SEASONAL WATER SUPPLY, WATER REQUIREMENTS, CONTRIBUTIONS TO GROUND WATER AND WATER SUPPLY REMAINING IN STORAGE AT END OF EACH SEASON IN UNDERGROUND RESERVOIRS, IN ABSORPTIVE AREAS OF UPPER SAN JOAQUIN VALLEY UNDER MODIFIED PLAN OF OPERATION FOR ULTIMATE DEVELOPMENT DURING PERIOD 1917-1931

(Quantities, in Acre-feet)

Season	Utilizable local water supply	Utilizable imported water supply	Total utilizable water supply	Net use	Seasonal net contribution (+) to or extraction (—) from ground water	Water supply remaining in ground water storage
Hydrographic Division 4						
1916-17	------------	------------	------------	------------	------------	8,517,100
1917-18	1,361,900	------------	1,361,900	1,658,900	—297,000	8,220,100
1918-19	1,199,700	------------	1,199,700	1,658,900	—459,200	7,760,900
1919-20	1,398,100	------------	1,398,100	1,658,900	—260,800	7,500,100
1920-21	1,523,800	------------	1,523,800	1,658,900	—135,100	7,365,000
1921-22	2,010,000	------------	2,010,000	1,658,900	+351,100	7,716,100
1922-23	1,599,800	------------	1,599,800	1,658,900	—59,100	7,657,000
1923-24	392,000	------------	392,000	1,658,900	—1,266,900	6,390,100
1924-25	1,285,900	------------	1,285,900	1,658,900	—373,000	6,017,100
1925-26	1,032,900	------------	1,032,900	1,658,900	—626,000	5,391,100
1926-27	1,973,500	------------	1,973,500	1,658,900	+314,600	5,705,700
1927-28	969,500	------------	969,500	1,658,900	—689,400	5,016,300
1928-29	847,600	------------	847,600	1,658,900	—811,300	4,205,000
1929-30	862,800	------------	862,800	1,658,900	—796,100	3,408,900
1930-31	465,800	------------	465,800	1,658,900	—1,193,100	2,215,800
Totals	16,923,300	------------	16,923,300	23,224,600	—6,301,300	
Average	1,208,800	------------	1,208,800	1,658,900	—450,100	
Hydrographic Division 6						
1916-17	------------	------------	------------	------------	------------	2,284,100
1917-18	99,700	149,000	248,700	368,000	—119,300	2,164,800
1918-19	99,700	134,300	234,000	368,000	—134,000	2,030,800
1919-20	81,000	130,000	211,000	368,000	—157,000	1,873,800
1920-21	99,700	154,900	254,600	368,000	—113,400	1,760,400
1921-22	99,700	366,800	466,500	368,000	+98,500	1,858,900
1922-23	99,700	171,500	271,200	368,000	—96,800	1,762,100
1923-24	99,700	63,600	163,300	368,000	—204,700	1,557,400
1924-25	99,700	127,100	226,800	368,000	—141,200	1,416,200
1925-26	86,800	122,500	209,300	368,000	—158,700	1,257,500
1926-27	97,900	314,800	412,700	368,000	+44,700	1,302,200
1927-28	99,700	121,100	220,800	368,000	—147,200	1,155,000
1928-29	82,500	87,000	169,500	368,000	—198,500	956,500
1929-30	51,200	86,000	137,200	368,000	—230,800	725,700
1930-31	10,100	55,400	65,500	368,000	—302,500	423,200
Totals	1,207,100	2,084,000	3,291,100	5,152,000	—1,860,900	
Average	86,200	148,900	235,100	368,000	—132,900	

With the modified plan of operation there would have been some water remaining in ground water storage at the end of the season 1930–31 in each hydrographic division, after furnishing the full ultimate net use requirements in each season during the period 1917–31 analyzed. Therefore, the studies demonstrate that, with the modified plan of operation involving a change in allocation of supplemental supplies from Friant Reservoir and an equal degree of utilization of all underground reservoirs in the upper San Joaquin Valley, the proposed ultimate plan of development for the upper San Joaquin Valley is adequate to meet the ultimate requirements.

Hydro-graphic Divi-sion	De	Water requirements			Deficiency	
		served by supply lowance)	For areas served by pumping from ground water at 2.0 acre-feet per acre, in acre-feet	Totals in acre-feet	In acre-feet	In per cent of require-ments
		Acre-feet				
1a	North of Poso Cre San Joaquin Ri	34,000	------------	34,000	0	0
1b	Between Kern Ri 200 feet above]	72,000	------------	72,000	0	0
1d	South of Kern Ri Kern River Cai	116,000	------------	116,000	0	0
1f	West side rim lan Mendota-West	434,000	------------	434,000	134,000	31
1	Valley lands, incl in 1a, 1b, 1d an	153,000	773,000	926,000	0	0
	Totals, Hydr	809,000	773,000	1,582,000	------------	------------
2a	East side rim land Joaquin River-I	156,000	------------	156,000	0	0
2b	East side rim land San Joaquin Ri	62,000	------------	62,000	0	0
	sions from Tule	20,000	------------	20,000	10,000	50
2c	Land served entir					
2d	Lands served by conduits	26,000	------------	26,000	13,000	50
2e	West side rim lan Mendota-West	148,000	------------	148,000	46,000	31
2	Valley lands, excl	92,000	628,000	720,000	0	0
	Totals, Hydr	504,000	628,000	1,132,000	------------	------------
3	Valley lands, inclu	161,000	379,000	540,000	0	0
4	Valley lands, inclu	466,000	1,194,000	1,660,000	0	0
5	Kettleman Hills t	520,000	------------	520,000	160,000	31
5B	Kettleman Hills t	442,000	------------	442,000	136,000	31
6	Valley lands, exclu	65,000	303,000	368,000	0	0
6	Columbia Canal a	26,000	------------	26,000	8,000	31
	Totals, Hydr	91,000	303,000	394,000	------------	------------

80997A—Bet. pp. 626 a

TABLE D-12

SUMMARY OF WATER REQUIREMENTS AND WATER SUPPLY FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS, FOR SEASON 1930-1931

Hydrographic Division	Description of area to be served	Net irrigable area to be served, in acres	Sources of water supply			Utilizable water supply in acre-feet								Areas served by surface supply in acres	Areas served by ground water supply in acres	Water requirements				Deficiency	
						Surface supply						Supply available in underground reservoir at beginning of season	Total utilizable supply			For areas served by surface supply (gross allowance)		For areas served by pumping from ground water at 2.0 acre-feet per acre, in acre-feet	Totals in acre-feet	In acre-feet	In per cent of requirements
						From San Joaquin River Basin				From Sacramento River Basin	Totals										
			Local	Return flow and unregulated surplus	Imported	San Joaquin River at Friant	Local streams	Return flow and unregulated surplus	Totals							Acre-feet per acre	Acre-feet				
1a	North of Poso Creek, to be served by pumping lifts above the San Joaquin River-Kern County Canal	17,000			San Joaquin River	34,000			34,000		34,000		34,000	17,000		2.0	34,000		34,000	0	0
1b	Between Kern River and Poso Creek, within pumping lifts of 200 feet above Beardsley and Lerdo canals	36,000	Kern River and Poso Creek				72,000		72,000		72,000		72,000	36,000		2.0	72,000		72,000	0	0
1d	South of Kern River within pumping lifts of 350 feet above Kern River Canal	58,000	Kern River and minor streams				116,000		116,000		116,000		116,000	58,000		2.0	116,000		116,000	0	0
1f	West side rim lands above elevation 250 feet, to be served by Mendota-West Side Pumping System	217,000		Lower San Joaquin Valley	Sacramento River			54,000	54,000	246,000	300,000		300,000	217,000		2.0	434,000		434,000	134,000	31
1	Valley lands, including municipal areas, and excluding areas in 1a, 1b, 1d and 1f	463,000	Kern River and minor streams		San Joaquin River	127,000	26,000		153,000		153,000	1,346,000	1,499,000	76,500	386,500	2.0	153,000	773,000	926,000	0	0
	Totals, Hydrographic Division 1	791,000				161,000	214,000	54,000	429,000	246,000	675,000	1,346,000	2,021,000	404,500	386,500	2.0	809,000	773,000	1,582,000		
2a	East side rim lands within pumping lifts of 250 feet above San Joaquin River-Kern County Canal	78,000			San Joaquin River	156,000			156,000		156,000		156,000	78,000		2.0	156,000		156,000	0	0
2b	East side rim lands to be served jointly by pumping lifts from San Joaquin River-Kern County Canal and gravity diversions from Tule River	31,000			San Joaquin River	62,000			62,000		62,000		62,000	31,000		2.0	62,000		62,000	0	0
2c	Land served entirely by gravity diversions from Tule River	10,000	Tule River and Deer Creek				10,000		10,000		10,000		10,000	10,000		2.0	20,000		20,000	10,000	50
2d	Lands served by pumping lifts from Tule River diversion conduits	13,000	Tule River and Deer Creek				13,000		13,000		13,000		13,000	13,000		2.0	26,000		26,000	13,000	50
2e	West side rim lands above elevation 250 feet, to be served by Mendota-West Side Pumping System	74,000		Lower San Joaquin Valley	Sacramento River			19,000	19,000	83,000	102,000		102,000	74,000		2.0	148,000		148,000	46,000	31
2	Valley lands, excluding areas in 2a, 2b, 2c, 2d and 2e	360,000			San Joaquin River	92,000			92,000		92,000	1,495,000	1,587,000	46,000	314,000	2.0	92,000	628,000	720,000	0	0
	Totals, Hydrographic Division 2	566,000				310,000	23,000	19,000	352,000	83,000	435,000	1,495,000	1,930,000	252,000	314,000	2.0	504,000	628,000	1,132,000		
3	Valley lands, including municipal areas	270,000	Kaweah River and minor streams		San Joaquin River	28,000	133,000		161,000		161,000	404,000	565,000	80,500	189,500	2.0	161,000	379,000	540,000	0	0
4	Valley lands, including municipal areas	830,000	Kings River				466,000		466,000		466,000	3,408,000	3,874,000	233,000	597,000	2.0	466,000	1,194,000	1,660,000	0	0
5	Kettleman Hills to Mendota, below elevation 350 feet	260,000		Lower San Joaquin Valley	Sacramento River			65,000	65,000	295,000	360,000		360,000	260,000		2.0	520,000		520,000	160,000	31
5B	Kettleman Hills to Mendota, above elevation 350 feet	221,000		Lower San Joaquin Valley	Sacramento River			56,000	56,000	250,000	306,000		306,000	221,000		2.0	442,000		442,000	136,000	31
6	Valley lands, exclusive of Columbia Canal area	184,000	Chowchilla, Fresno and San Joaquin rivers			55,000	10,000		65,000		65,000	726,000	791,000	32,500	151,500	2.0	65,000	303,000	368,000	0	0
6	Columbia Canal area	13,000		Lower San Joaquin Valley	Sacramento River			9,000	9,000	9,000	18,000		18,000	13,000		2.0	26,000		26,000	8,000	31
	Totals, Hydrographic Division 6	197,000				55,000	10,000	9,000	74,000	9,000	83,000	726,000	809,000	45,500	151,500	2.0	91,000	303,000	394,000		

80997A—Bet. pp. 626 and 627

TABLE D-12—Continued

SUMMARY OF WATER REQUIREMENTS AND WATER SUPPLY FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS, FOR SEASON 1930-1931

Hydrographic Division	Description of area to be served	Net irrigable area to be served, in acres	Sources of water supply: Local	Sources of water supply: Return flow and unregulated surplus	Sources of water supply: Imported	Utilizable water supply in acre-feet: Surface supply: From San Joaquin River Basin: San Joaquin River at Friant	From San Joaquin River Basin: Local streams	From San Joaquin River Basin: Return flow and unregulated surplus	From San Joaquin River Basin: Totals	From Sacramento River Basin	Surface supply: Totals	Supply available in underground reservoir at beginning of season	Total utilizable supply	Areas served by surface supply in acres	Areas served by ground water supply in acres	Water requirements: For areas served by surface supply (gross allowance): Acre-feet per acre	For areas served by surface supply (gross allowance): Acre-feet	For areas served by pumping from ground water at 2.0 acre-feet per acre, in acre-feet	Totals in acre-feet	Deficiency: In acre-feet	Deficiency: In per cent of requirements
7	West side area, south of Merced River, exclusive of rim lands	203,000		Lower San Joaquin Valley	Sacramento River			227,000	227,000	242,000	469,000		469,000	203,000		3.3	670,000		670,000	201,000	30
7	West side area, north of Merced River, exclusive of rim lands	62,000		Lower San Joaquin Valley				85,000	85,000		85,000		85,000	62,000		2.0	124,000		124,000	39,000	3
7a	Rim lands, above present irrigated areas	143,000		Lower San Joaquin Valley	Sacramento River			54,000	54,000	141,000	195,000		195,000	143,000		2.0	286,000		286,000	91,000	2
	Totals, Hydrographic Division 7	408,000						366,000	366,000	383,000	749,000		749,000	408,000		2.6	1,080,000		1,080,000		
8A	Foothills, below Exchequer Reservoir	28,000	Merced River				84,000		84,000		84,000		84,000	28,000		3.0	84,000		84,000	0	0
8	Valley lands, exclusive of area served from San Joaquin River	213,000	Merced River	Merced River			102,000	60,000	162,000		162,000	556,000	718,000	49,000	164,000	3.3	162,000	328,000	490,000	0	0
8	Area served from San Joaquin River	69,000		Lower San Joaquin Valley	Sacramento River			76,000	76,000	83,000	159,000		159,000	69,000		3.3	226,000		226,000	67,000	30
	Totals, below Exchequer Reservoir, hydrographic divisions 8 and 8A	310,000					186,000	136,000	322,000	83,000	405,000	556,000	961,000	146,000	164,000	3.2	472,000	328,000	800,000		
9A	Foothills, below Don Pedro Reservoir	47,000	Tuolumne River				141,000		141,000		141,000		141,000	47,000		3.0	141,000		141,000	0	0
9	Valley lands	312,000	Tuolumne River				437,000		437,000		437,000	1,163,000	1,600,000	132,000	180,000	3.3	437,000	360,000	797,000	0	0
	Totals, below Don Pedro Reservoir, hydrographic divisions 9 and 9A	359,000					578,000		578,000		578,000	1,163,000	1,741,000	179,000	180,000	3.2	578,000	360,000	938,000		
10	West delta uplands	69,000			Sacramento River					94,000	94,000		94,000	69,000		2.0	138,000		138,000	44,000	32
11A	Foothills, below Melones Reservoir	30,000	Stanislaus River				77,000		77,000		77,000		77,000	30,000		2.6	77,000		77,000	0	0
11	Valley lands	260,000	Stanislaus River	Stanislaus River	American River		144,000	72,000	216,000	81,000	297,000	335,000	632,000	90,000	170,000	3.3	297,000	340,000	637,000	5,000	1
	Totals, below Melones Reservoir, hydrographic divisions 11 and 11A	290,000					221,000	72,000	293,000	81,000	374,000	335,000	709,000	120,000	170,000	3.1	374,000	340,000	714,000		
12A	Foothills, below Valley Springs Reservoir	7,000	Calaveras River				12,000		12,000		12,000		12,000	7,000		2.5	17,000		17,000	5,000	29
12	Valley lands, below Valley Springs Reservoir	53,000	Calaveras River									138,000	138,000		53,000			106,000	106,000	0	0
12A	Foothills, below Pardee and Ione reservoirs	22,000	Mokelumne River and Dry Creek				41,000		41,000		41,000		41,000	22,000		2.5	55,000		55,000	14,000	25
12	Valley lands, below Pardee and Ione reservoirs	165,000	Mokelumne River and Dry Creek				45,000		45,000		45,000	382,000	427,000	17,000	148,000	2.7	45,000	296,000	341,000	0	0
	Totals, below reservoirs, hydrographic divisions 12 and 12A	247,000					98,000		98,000		98,000	520,000	618,000	46,000	201,000	2.5	117,000	402,000	519,000		
13	Valley lands	127,000	Cosumnes River		American River		24,000		24,000	204,000	228,000		228,000	127,000		2.7	343,000		343,000	115,000	34

80997B—Bet. pp. 626 and 627

Water Supply for Season 1930–31 by Hydrographic Divisions—The supplemental analyses of water supply extended through the seasons 1929–30 and 1930–31 under the ultimate State Water Plan in the San Joaquin River Basin show that the critical season testing the adequacy of the proposed physical units would be that of 1930–31. Accordingly, a final demonstration of the adequacy of the plan may be obtained by comparing the utilizable water supplies that would have been available in the season 1930–31 under the modified plan of operation previously described with the water requirements. This final demonstration is set forth in Table D-12 which shows by hydrographic divisions and zones of service the available utilizable water supply for the season 1930–31 from all sources including surface water supplies in the San Joaquin River Basin, ground water supplies, return flow and unregulated surplus waters and imported supplies from the Sacramento River Basin. The table also shows by hydrographic divisions and zones of service the irrigable areas to be served, the areas and water requirements served by surface water supplies, the areas and water requirements served by ground water supplies, the total water requirements and finally the deficiency, if any, between supply and requirements.

The data in Table D-12 show that the water supply obtainable in the season 1930–31, the critical season of the entire period, would have been generally adequate for all areas in the San Joaquin River Basin. The deficiency would not have exceeded 35 per cent in any hydrographic division or zone of service with the exception of zones (c) and (d) in Hydrographic Division No. 2 wherein the deficiency on 23,000 acres would have reached 50 per cent. The greater deficiency in these two zones might be met by additional minor modifications in the plan of operation, as for example an increase in the area of service in zone 2(b) and a corresponding decrease in zone 2(c). Other minor modifications might be made which would improve the plan of operation, after more detailed study and with longer records of run-off. However, it is believed that the detailed analyses presented demonstrate that the proposed ultimate State Water Plan in the San Joaquin River Basin would be adequate and dependable for providing the ultimate water requirements in the San Joaquin River Basin even over an extended dry period such as the one experienced from 1917 to 1931, inclusive.

Performance of Ultimate State Water Plan in Great Central Valley—The performance of the ultimate State Water Plan in the entire Great Central Valley for the 14-year period 1918–1931 is set forth in Table D-13. For comparison, the accomplishments based upon the study for the 11-year period 1918–1929, as previously set forth in Chapter VII, also are shown.

For the period 1918–1931, there would have been some deficiencies in 1924 and 1931. It should be noted, however, that in only one relatively small area would the deficiency have exceeded 35 per cent in any month and that in most instances the seasonal or yearly supply would have been much less than 35 per cent deficient. Occasional deficiencies of such magnitude in water supplies are not serious and can be endured.

However, if it should be desirable to have perfect supplies in years of deficient precipitation, or supplies with only small and infrequent shortages, the necessary additional water supplies could be obtained in several ways, namely by increasing the storage capacity in the Sacramento River Basin, by the use of ground water in that basin, by the importation of water from the upper Klamath and Eel rivers, or by a combination of any or all of these methods.

TABLE D-13

PERFORMANCE OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY IN CRITICAL PERIODS 1918-1929 AND 1918-1932 OF FORTY TWO-YEAR PERIOD 1890-1932

Item	Accomplishments in period	
	1918-1929	1918-1932
1. A supply of 9,033,000 acre-feet per season, gross allowance, available in the principal streams, for the irrigation of the net area of 2, 640,000 acres of irrigable lands of all classes on the Sacramento Valley floor.	Full supply in all years	Full supply in all years except 1931. Deficiencies in that year—seasonal, 32 per cent; maximum in any area, 35 per cent.
2. A supply of 1,200,000 acre-feet per season for the irrigation of all the net area of 392,000 acres of irrigable lands, and for unavoidable losses, in the Sacramento-San Joaquin Delta.	Full supply in all years	Full supply in all years except 1931. Deficiencies in that year—seasonal and maximum monthly, 32 per cent.
3. A fresh water flow of 3,300 second-feet past Antioch into Suisun Bay for the control of salinity to the lower end of the delta.	Full supply in all years	Full supply in all years except 1931. Deficiencies in that year—seasonal, 19 per cent; maximum monthly, 32 per cent.
4. A supply of 5,342,000 acre-feet per season, gross allowance, for the irrigation of the net area of 1,810,000 acres of irrigable lands of all classes in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley below the major reservoir units.	Full supply in all years except 1924. Seasonal deficiency of 35 per cent in supply of 896,000 acre-feet for "crop lands" in 1924.	Full supply in all years except 1924 and 1931. Deficiency in 1924 same as shown in preceding column. Deficiencies in 1931—seasonal, 26 per cent; maximum in any area, 35 per cent.
5. A supply of 4,700,000 acre-feet per season for the irrigation of a net area of 2,350,000 acres of class 1 and 2 lands on the eastern and southern slopes of the Upper San Joaquin Valley.	Full supply in all years	Full supply in all years except 1931. Deficiency in that year of 50 per cent in supply for an area of 23,000 acres dependent upon Tule River.
6. A supply of 1,570,000 acre-feet per season for the irrigation of the net irrigable area of 785,000 acres of class 1 and 2 lands lying on the western slope of the Upper San Joaquin Valley.	Full supplies in all years except 1924. Seasonal deficiency of 35 per cent in that year.	Full supply in all years except 1924 and 1931. Seasonal deficiencies in those years, 35 per cent.
7. A water supply and channel depth in the San Joaquin River sufficient to provide a navigable depth of six feet as far upstream as Salt Slough, nine miles above the Merced River.	Fully maintained in all years	Fully maintained in all years.
8. A supply of 403,000 acre-feet per year, in the Sacramento-San Joaquin Delta, for use in the San Francisco Bay Basin. Of this, 80,000 acre-feet are allotted to industrial use and 323,000 acre-feet to irrigation.	Full supply in all years except 1924. Annual deficiency of 35 per cent in 1924 in the irrigation supply.	Full supply in all years except 1924 and 1931. Deficiency in 1924 same as shown in preceding column. Maximum monthly deficiency in 1931—32 per cent in both industrial and irrigation supplies. Annual deficiency in industrial supply, 19 per cent, and in irrigation supply, 30 per cent.

Probable Frequency of Occurrence of Seasons and Consecutive Seasons of Subnormal Run-off.

The adequacy of the units for the initial and ultimate developments of the State Water Plan for the Great Central Valley has been tested through the period 1917–1931 having the lowest run-off of record. Considering the entire period 1889–1931, it is found that the units proposed would have furnished adequate and dependable supplies for all purposes and to all areas in accord with the objectives sought to be obtained in each plan of development. In the Sacramento River Basin, it has been determined from the records of run-off and precipitation from 1889 to 1931 that a surplus of water exists, over and above the ultimate water requirements in that basin, which would be adequate in amount to provide the supplemental supplies required in the San Joaquin River Basin for its ultimate requirements. Under the ultimate State Water Plan, a maximum deficiency in some instances of not to exceed 35 per cent would have occurred in only two seasons during the entire 42-year period, namely the seasons 1923–1924 and 1930–1931. Such a deficiency occurring only at infrequent intervals is not serious and it is doubtful if it would be economic to provide a perfect supply in such abnormally dry seasons.

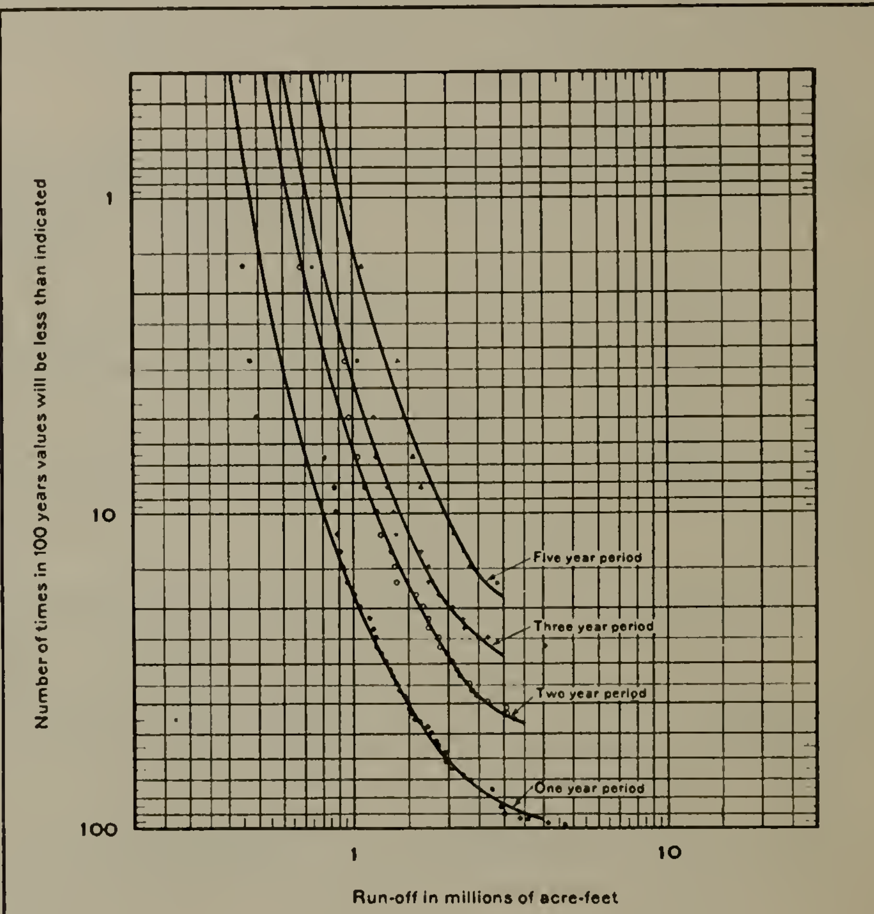
However, it is important to determine as accurately as practicable the probable frequency of occurrence of seasons and consecutive seasons of low run-off because it is such periods which determine the dependable amounts of water supply for any particular project. In order that some idea may be obtained of the magnitude and probable frequency of occurrence of low run-offs in the San Joaquin River Basin and also in the Sacramento River Basin, a study was made utilizing all available information on run-off and precipitation in the two basins. The study was divided into two parts. The first part pertains to the upper San Joaquin River on which Friant Reservoir, the initial unit in the San Joaquin River Basin, is located; and the second to the entire Great Central Valley.

Upper San Joaquin River—The data used in the analyses comprise the seasonal run-offs from October 1, 1871, to October 1, 1932, or a period of 61 years. The values used are the full natural run-offs unimpaired by upstream storage for power regulation. Values are based on actual measurements of the run-off of the San Joaquin River at Herndon from 1894 to 1901 and from measurements at Friant from 1907 to 1932. Prior to 1894, the values have been estimated by means of curves developed to show the relation between precipitation and run-off for periods of stream flow record. The estimated seasonal run-offs for the period 1889–1931 are shown in Table 5 of Chapter II and Table D-2 of this appendix; and those from 1871 to 1889 are given in Table 77, Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works.

Analyses were made to estimate the probable frequency of occurrence of single seasons, and also two, three and five consecutive seasons, of low run-off. In making the analysis for the single season, or one-year periods, the seasonal values of run-off were arranged and numbered in order of increasing magnitude. The number assigned to any particular seasonal run-off value gave the frequency with which seasonal run-offs equal to or less than that particular value had occurred during the period analyzed. These numbers were then converted to values representing frequencies in 100 years. Each frequency value represented the number of times in 100 years for which the seasonal run-off would be equal to or less than the corresponding seasonal run-off. These values of seasonal run-offs were plotted on logarithmic scale paper in accord with their respective frequencies. A smooth curve interpreting the trend of the data was drawn and extended to a frequency of 0.4

in 100 years. Analyses of the mean seasonal run-offs for consecutive two, three and five-season periods were made in a similar manner. These analyses, delineated on Plate D-1, "Probable Frequencies of Mean Seasonal Run-offs from Upper San Joaquin River above Friant," are an empirical interpretation of all the available data and are believed to be indicative, at least, of the frequency of occurrence of various magnitudes of seasonal run-offs in single seasons and mean seasonal run-offs during consecutive two, three and five-season periods.

PLATE D–I



PROBABLE FREQUENCIES
OF MEAN SEASONAL RUN-OFFS
FROM
UPPER SAN JOAQUIN RIVER BASIN ABOVE FRIANT

The average frequencies with which the low run-offs of several recent seasons, and periods of consecutive seasons are likely to occur, are set forth in Table D-14.

It may be noted that a seasonal run-off of less than the 446,000 acre-feet for the season 1923–1924 would be expected to occur once in 147 years and that for the season 1930–1931, once in 80 years.

Great Central Valley—Analyses similar to those for the upper San Joaquin River above Friant were made for the entire San Joaquin River Basin, for the Sacramento River Basin and for the combined basins to estimate the probable frequencies of occurrence of seasonal run-offs of varying magnitudes. As in the case of the upper San Joaquin River, the values used in the analyses are the full natural run-offs. For these analyses, the run-offs from mountainous areas of the major streams, only, were used. Those for the minor streams and unmeasured areas were not included. They represent less than 10 per cent of the total run-off from the basins. Graphs similar to those for the upper San Joaquin River were prepared and are presented herewith as Plate D-II, "Probable Frequencies of Mean Seasonal Run-offs from Major Streams of Sacramento and San Joaquin River Basins."

TABLE D-14

FREQUENCIES OF OCCURRENCE OF SEASONAL RUN-OFFS OF PERIOD 1915-1931 FROM UPPER SAN JOAQUIN RIVER ABOVE FRIANT

Based on seasonal run-offs for 61-year period 1871-1932.
Mean seasonal run-off, 1,981,000 acre-feet.

Period (Season October 1 through September 30th)	Mean seasonal run-off for period		Average frequency of occurrence (from curves on Plate D-I)
	In acre-feet	In per cent of mean seasonal run-off for period 1871-1932	
One-year periods—			
1919-1920	1,320,000	67	Once in 3 years
1923-1924	446,000	23	Once in 147 years
1928-1929	873,000	44	Once in 8 years
1930-1931	489,000	25	Once in 80 years
Two-year periods—			
1922-1924	1,053,000	53	Once in 13 years
1929-1931	684,000	35	Once in 64 years
Three-year periods—			
1917-1920	1,365,000	69	Once in 11 years
1921-1924	1,488,000	75	Once in 9 years
1928-1931	747,000	38	Once in 83 years
Five-year periods—			
1915-1920	1,765,000	89	Once in 13 years
1919-1924	1,477,000	75	Once in 20 years
1921-1926	1,416,000	71	Once in 22 years
1926-1931	1,084,000	55	Once in 53 years

Values of frequency of occurrence of mean seasonal run-offs during several recent seasons and periods of two, three and five consecutive seasons have been taken from the developed curves on Plate D-II and are tabulated in Table D-15. These values are presented for the San Joaquin River Basin alone, the Sacramento River Basin alone, and for the combined basins.

An inspection of the figures in the table reveals that the run-off may be expected to be less than that of the season 1923–1924, the season of lowest run-off, once in 128 years for the San Joaquin River Basin, once in 130 years for the Sacramento River Basin and once in 147 years for the combined basins. The corresponding figures for the smallest mean seasonal run-off for two consecutive seasons are once in 43 years for the San Joaquin River Basin in 1929–1931, once in 26 years for the Sacramento River Basin in 1922–1924, and once in 33 years for the combined basins in 1929–1931. Similarly, the corresponding figures for the three run-off seasons 1928–1931, the driest three consecutive seasons during the period 1918–1931, are once in 62 years for San Joaquin River Basin, once in 62 years for the Sacramento River Basin, and once in 77 years for the combined basins.

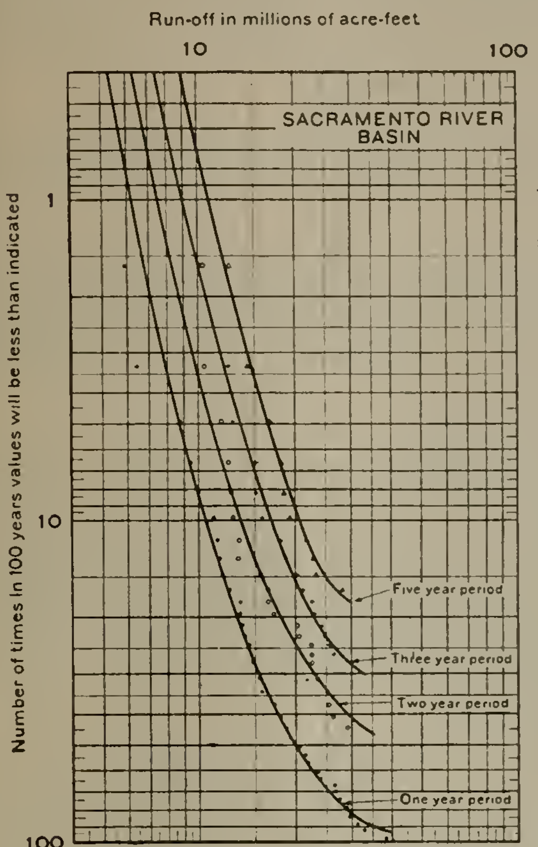
TABLE D-15

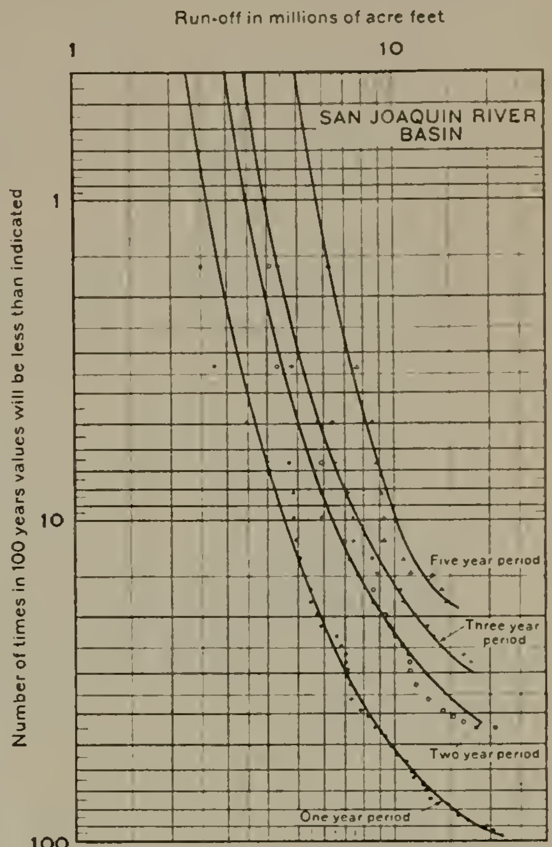
FREQUENCIES OF OCCURRENCE OF SEASONAL RUN-OFFS OF PERIOD 1916-1931 IN GREAT CENTRAL VALLEY OF CALIFORNIA

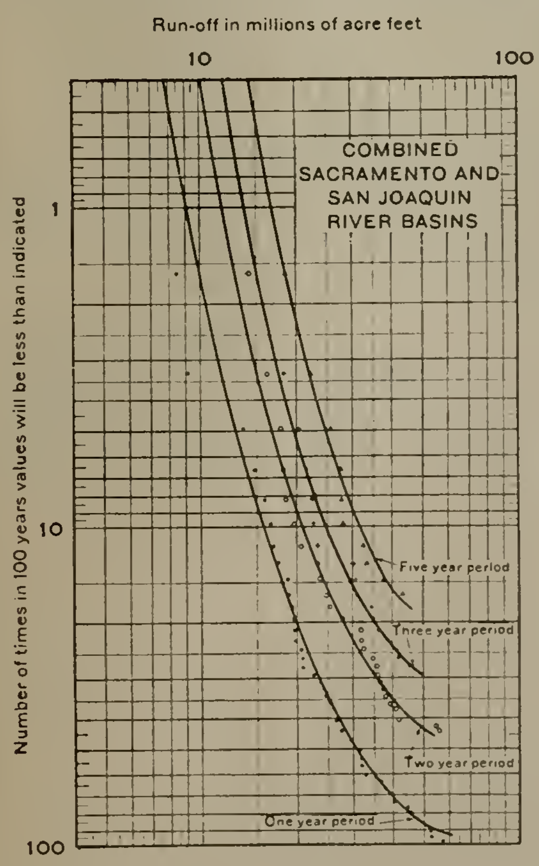
Based on Seasonal Run-offs of Major Streams for 61-year Period, 1871-1932

Period (Season October 1st through September 30th)	San Joaquin River Basin			Sacramento River Basin			Combined Sacramento and San Joaquin River basins		
	Mean seasonal run-off, 1871-1932, 10,880,000 acre-feet			Mean seasonal run-off, 1871-1932, 21,570,000 acre-feet			Mean seasonal run-off, 1871-1932, 32,450,000 acre-feet		
	Mean seasonal run-off for period		Average frequency of occurrence (from curves on Plate D-II)	Mean seasonal run-off for period		Average frequency of occurrence (from curves on Plate D-II)	Mean seasonal run-off for period		Average frequency of occurrence (from curves on Plate D-II)
	In acre-feet	In per cent of mean seasonal run-off for period 1871-1932		In acre-feet	In per cent of mean seasonal run-off for period 1871-1932		In acre-feet	In per cent of mean seasonal run-off for period 1871-1932	
One year periods—									
1919-1920	7,340,000	67	Once in 3 years	9,540,000	44	Once in 14 years	16,880,000	52	Once in 8 years
1923-1924	2,500,000	23	Once in 128 years	5,960,000	28	Once in 130 years	8,460,000	26	Once in 147 years
1928-1929	4,840,000	44	Once in 8 years	8,870,000	41	Once in 18 years	13,710,000	42	Once in 16 years
1930-1931	2,740,000	25	Once in 75 years	6,440,000	30	Once in 85 years	9,180,000	28	Once in 96 years
Two-year periods—									
1918-1920	7,280,000	67	Once in 8 years	13,320,000	62	Once in 10 years	20,600,000	63	Once in 10 years
1922-1924	5,990,000	55	Once in 12 years	10,300,000	48	Once in 26 years	16,280,000	50	Once in 21 years
1927-1929	5,960,000	55	Once in 12 years	13,680,000	63	Once in 10 years	19,640,000	61	Once in 12 years
1928-1930	5,160,000	47	Once in 18 years	11,840,000	55	Once in 16 years	17,000,000	52	Once in 18 years
1929-1931	4,120,000	38	Once in 43 years	10,630,000	49	Once in 23 years	14,750,000	45	Once in 33 years
Three-year periods—									
1917-1920	7,440,000	68	Once in 11 years	12,760,000	59	Once in 25 years	20,200,000	62	Once in 18 years
1923-1926	5,800,000	53	Once in 20 years	12,450,000	58	Once in 27 years	18,250,000	56	Once in 26 years
1928-1931	4,360,000	40	Once in 62 years	10,040,000	47	Once in 62 years	14,400,000	44	Once in 77 years
Five-year periods—									
1916-1921	8,820,000	81	Once in 16 years	16,760,000	78	Once in 19 years	25,580,000	79	Once in 18 years
1921-1926	7,980,000	73	Once in 22 years	14,280,000	66	Once in 32 years	22,260,000	69	Once in 29 years
1922-1927	7,680,000	71	Once in 26 years	15,720,000	73	Once in 23 years	23,400,000	72	Once in 24 years
1926-1931	6,330,000	58	Once in 61 years	15,050,000	70	Once in 27 years	21,380,000	66	Once in 33 years

PLATE D–II







PROBABLE FREQUENCIES

OF

MEAN SEASONAL RUN-OFFS

FROM

MAJOR STREAMS

OF

SACRAMENTO AND

SAN JOAQUIN RIVER BASINS

Summary.

The studies made to test the adequacy of the initial and ultimate major units of the State Water Plan and to estimate the probable frequency of occurrence of single and consecutive seasons of subnormal run-off such as those used in these tests, show that:

(1) The objectives sought to be accomplished by the units for the immediate initial development would have been fully met throughout the 42-year period 1889–1931.

(2) The objectives sought to be accomplished by the units for complete initial development would have been fully met throughout the 42-year period 1889–1931, except in the season of 1930–31. In that season there would have been bearable deficiencies in the irrigation supply much less than those obtained under existing conditions, for the lower San Joaquin Valley "crop lands."

(3) The objectives sought to be accomplished by the major units of the ultimate State Water Plan for the Great Central Valley would have been fully met throughout the 42-year period 1889 to 1931, except in the seasons 1923–24 and 1930–31. In these two seasons, the deficiencies occurring would be bearable, except for a limited area of foothill lands in the San Joaquin River Basin in the season 1930–31. Minor modifications in the plan of operation would reduce the deficiency to bearable amounts for these lands.

(4) Low seasonal run-offs such as those which occurred in the seasons 1923–24 and 1930–31, and in the three consecutive seasons 1928–1931, in the upper San Joaquin River watershed, and which were used in the tests of the adequacy of the Friant Reservoir unit in the initial development, may be expected to occur with average frequencies of once in 147 years, once in 80 years and once in 83 years, respectively.

(5) Low seasonal run-offs such as those which occurred in the seasons 1923–1924 and 1930–1931, and in the three consecutive seasons 1928–1931, in the Great Central Valley, and which were used in the tests of the adequacy of the ultimate State Water Plan for this valley, may be expected to occur with the following average frequencies:

Period	*San Joaquin River Basin*	*Sacramento River Basin*	*Combined Sacramento and San Joaquin River Basins*
1923–1924	Once in 128 years	Once in 130 years	Once in 147 years
1930–1931	Once in 75 years	Once in 85 years	Once in 96 years
1928–1931	Once in 62 years	Once in 62 years	Once in 77 years

APPENDIX E

THE CHEMICAL CHARACTER OF SOME SURFACE WATERS OF CALIFORNIA, 1930–1932

by

S. K. Love

Assistant Chemist

Quality of Water Division

United States Geological Survey

TABLE OF CONTENTS

THE CHEMICAL CHARACTER OF SOME SURFACE WATERS OF CALIFORNIA, 1930–1932

Introduction.

A comprehensive study of the chemical character of surface waters in California was made by Van Winkle and Eaton in 1906–8 and reported in United States Geological Survey Water-Supply Paper 237, published in 1910. The major part of this work consisted of complete mineral analyses of 10-day composites of daily samples collected over a period of a year at 33 points on 30 streams, with a few analyses of single samples.

The extensive development of irrigation since 1908, including the building of dams for storage reservoirs, has made a decided change in the character of some of the waters. In some of the drainage basins, however, comparatively little change has taken place.

In order to obtain some indication of the present value of the older analyses, a brief preliminary survey was made in 1930 as part of the cooperative work on waters being conducted by the United States Geological Survey and the State Department of Public Works. In this survey 145 samples were collected at 69 points on 56 streams. During the period from July 20, 1931, to January 1, 1932, samples were collected about twice a week from the Sacramento River at the M Street Bridge in Sacramento, and from January 1 to July 13, 1932, samples were collected on the average once a week. Altogether 71 samples were taken at this point. All samples were sent to Washington for analysis.

The samples collected in 1930 were collected by or under the direction of H. D. McGlashan, district engineer of the Geological Survey, at San Francisco, for the northern part of the State, and by F. C. Ebert, of the Los Angeles office of the Geological Survey, for the southern part of the State. The samples from the Sacramento River in 1931–32 were collected under the direction of Edward Hyatt, State engineer of California. Mr. Hyatt and Mr. McGlashan furnished discharge data, information as to the general conditions at the sampling points, and explanations of some of the results shown by examination of the samples.

The examination of the single small samples collected in 1930 was little more than is covered by the so-called "preliminary examination"[1] made to determine the approximate composition of samples received in the laboratory. This included regular determinations of carbonate, bicarbonate, chloride, nitrate, and hardness by the soap method, turbidimetric determinations of calcium and sulphate, and approximate determination of boron. Calcium, magnesium, and sulphate were determined in the regular way in several samples that contained large enough quantities to be determined in the small volume of water available. These partial analyses are almost as valuable as complete analyses for single samples of surface waters. Such occasional samples can not show the character of a water throughout the year, but they give

[1] Collins, W. D., Notes on practical water analysis: U. S. Geol. Survey Water-Supply Paper 596-H, p. 238, 1927.

reasonably clear indications of changes or lack of changes in composition of the water since the earlier work was done.

The samples from the Sacramento River at Sacramento were analyzed according to the methods regularly used by the Geological Survey for the complete analysis of the mineral content of waters.[2] All the usual constituents present in determinable amounts were recorded, and in addition approximate determinations of boron were made. The results are of the same degree of reliability as those reported in Water-Supply Paper 237, with possibly some slightly greater accuracy on account of developments in analytical methods since the earlier work. In the analyses made in 1931–32 potassium was determined and several of the other determinations were made more carefully. Although the results do not cover the composition of the river water completely throughout the year, they do indicate the probable range in composition of the water. The earlier results had the advantage of including a small sample of water for each day in the year. When these small samples were made into composites covering 10 days the analysis gave an average composition of the water for the period covered.

The results obtained in 1930 are given in Table E-2. Those obtained for the complete analyses of samples from the Sacramento River in 1931–32 are given in Table E-3. Some comparisons between the earlier and later results at a few points are given in Table E-1.

Rainfall and discharge in 1906–8 and 1930–32.

Climatic records show that, in general, years of maximum precipitation have been accompanied or closely followed by years of high discharge. The investigation of 1906–8 was made at a time when the rainfall was for the most part considerably above the normal. The discharge of the Sacramento and Tuolumne Rivers was much above the normal, and records for other rivers in the State show the same trend. The samples taken in 1930 were collected during the period of low rainfall. In the two years prior to 1930 there had been a deficiency of 17 inches of rain, and during 1930 the rainfall was 7 inches below the normal, making a total deficiency of 24 inches for the 3-year dry period. With few exceptions the rivers of the State had discharges decidedly below normal during most of 1930.

The average rainfall in 1931 was only 1.15 inches below the normal. A deficiency occurred between January and July, but for the remainder of the year it was mostly above the normal, particularly in December, when it was two to three times the monthly normal at many weather stations. During the first 7 months in 1932 there was a total deficiency of slightly over 4 inches. The analyses of the Sacramento River in 1931–32 were, therefore, made during a period of nearly normal precipitation. The discharge at Sacramento, however, was considerably below normal during the summer of 1931, owing to the heavy draft for irrigation.

Because of changing conditions with reference to the importance of different streams and the need for information concerning their discharges, there is a considerable difference between the sampling points in 1930 and those for which analyses were made in 1906–8. Strict comparisons between the two periods are possible only for the stations

[2] Collins, W. D., *op. cit.*

that are identical. For some of the others reasonably accurate comparisons can be made, but for some stations the only value of the new figures lies in their own worth as indicating roughly what kind of water is now available.

Identical sampling points, 1906–8 and 1930.

Of the 145 samples collected for analysis in 1930 only 24, taken at 12 places on 10 rivers, came from points identical with the sampling places of the earlier survey. From the analyses of the samples from identical sampling points the composition of the waters of the Yuba River at Smartsville, the Kern River near Bakersfield, Arroyo Seco near Soledad, and the San Gabriel River at Asusa seemed to be about the same as found by Van Winkle and Eaton.

The Feather River at Oroville, the American River at Fairoaks, the Stanislaus River at Knights Ferry, and the Santa Ana River near Mentone showed appreciable changes. They appeared to contain less chloride and sulphate in 1930, even though the discharge at several stations was but one-fourth to one-half that at corresponding periods in 1906–8. The sulphate, chloride, total hardness, and discharge of these rivers for the two periods are shown in Table E-1. The results for 1930 represent single samples on the dates shown. Those for 1906 and 1908 represent 8 to 23 day composites. The difference for the Stanislaus River may be accounted for in part by the passage of the water through the Melones Reservoir, which was constructed in 1926.

TABLE E-1

PARTIAL ANALYSES OF SOME CALIFORNIA SURFACE WATERS AT DIFFERENT PERIODS

	Sulphate (SO_4)	Chloride (Cl)	Total hardness as $CaCO_3$	Discharge in second-feet
Feather River at Oroville:				
May 8, 1930	4	.3	33	6,520
April 18-May 10, 1906	6.9	7.8	40	18,871
August 27, 1930	3	2.0	44	1,960
September 5-10, 1906	22	6.1	38	1,978
American River at Fair Oaks:				
May 8, 1930	1	.4	16	4,000
May 1-10, 1906	8.6	3.9	34	16,865
August 26, 1930	6	4.0	27	173
August 21-30, 1906	15	4.9	53	648
Stanislaus River at Knights Ferry:				
May 7, 1930	3	.4	20	1,420
May 2-10, 1906	17	3.9	30	9,264
Santa Ana River near Mentone:				
June 9, 1930	7	3.0	62	52
June 1-10, 1906	16	7.6	81	129
June 8-17, 1908	30	4.0	108	61.4

NOTE.—(Analyses in 1930 by S. K. Love; in 1906 and 1908 by Walton Van Winkle and F. M. Eaton. Analytical results in parts per million).

A sample from the Tuolumne River at La Grange, collected in May 1930, contained about the same quantity of mineral matter as was found in 1906; but a single sample in September was much lower in dissolved solids and particularly in calcium, sulphate, and chloride.

The discharge in May 1930 was about one-fifth that of 1906, but in September 1930 it was nearly 30 times greater, this being one of the few exceptions to the general condition of low flow in 1930. The greater discharge was probably due to releases from the Don Pedro Reservoir, constructed about 1923.

A single sample from the Ventura River near Ventura in May 1930 had much more calcium, magnesium, sulphate, and chloride and slightly less bicarbonate than were found by Van Winkle and Eaton. The quality of total solids was about 720 parts per million, which is higher than was reported for any composite sample during 1908.

Nearly identical sampling points in 1906–8 and 1930.

Fourteen samples were collected in 1930 from four rivers at points only short distances from the sampling points in 1906–8, and it seems safe to compare directly the results of the analyses. Five samples were taken between June and October from the Sacramento River at Verona, about 20 miles upstream from Sacramento, the sampling point during the earlier survey. The concentration seems to have been slightly less on days in June, September, and October but considerably more in July and August than at corresponding periods in 1906–8. No discharge figures are available for the Sacramento River at Sacramento or Verona during 1906–8, but the records obtained at Red Bluff, about 200 miles upstream from Sacramento, show that the discharge at that point was approximately twice as great in 1906–8 as at similar periods in 1930. The flow at Verona during the summer is reported to be made up largely of return water from rice irrigation.

Six samples were taken over a period of 6 months from the San Joaquin River near Vernalis, a short distance upstream from Lathrop. The difference in concentration was much greater between May and July 1930 than during a similar period in 1906. The analyses made in 1908 showed greater variation than those of 1906, but none made in May of either year showed as much dissolved matter as the sample collected May 16, 1930. There are no discharge records available for the San Joaquin River at Lathrop during 1906–8. The amount of irrigation, and consequently the amount of return water, above Vernalis was much greater in 1930 than in 1906–8.

The Merced River at Exchequer appeared to contain in 1930 less calcium, sulphate, and chloride than at Merced Falls, a short distance downstream, in 1906. The discharge was about one-fifth as great at Exchequer in 1930 as at Merced Falls in 1906. The water collected from the river at Exchequer in 1930 had passed through the Exchequer Reservoir, constructed about 1926.

One sample from the Owens River at Zurich in 1930 indicates little or no change. Calcium and magnesium were slightly higher than in 1908, but bicarbonate, sulphate, and chloride were a little lower. The discharge was about the same at both times.

Rivers sampled at different points in 1906–8 and 1930.

Among the 51 samples collected from 17 stations on 10 rivers at points other than those selected for the survey made by Van Winkle and Eaton, 18 came from 5 stations on the Sacramento River and 12 from 3 stations on the San Joaquin River. Both rivers showed a considerable range in amount of dissolved matter, but the range was greater for the San Joaquin. The hardness ranged from 50 to 132 parts per million in the Sacramento and from 3 to 169 parts per million in the San Joaquin. The total solids ranged from about 70 to 200 parts per million in the Sacramento and from about 20 to 450 parts per million in the San Joaquin. No discharge figures are available for any of the stations on the Sacramento River in 1906–8 except at Red Bluff; but records for three tributaries, the Feather, American, and Yuba Rivers, show that the discharge of these streams was about three times as great in 1906–8 as at corresponding periods in 1930. Records are similarly lacking for the San Joaquin River, but records for the main tributaries show that their discharge was three to five times as great in 1906 and about one-half as great in 1908 as at similar periods in 1930.

Two samples collected in 1930 from the Mokelumne River at Mokelumne Hill were less concentrated than those taken in 1906 at Clements, about 25 miles downstream. The discharge was about four times as great at Clements in 1906 as at Mokelumne Hill in 1930.

A single sample collected in 1930 from the San Benito River at Hernandez contained about five times as much magnesium as calcium, whereas in 1906 the concentrations of magnesium and calcium at Hollister, about 50 miles downstream, were nearly the same. No analyses of this or other tributaries are available, however, to indicate the character of the water that flows into the San Benito between Hernandez and Hollister. No discharge figures are available for either period.

The concentration of the Salinas River near San Miguel was very much greater than at Paso Robles, a few miles above San Miguel, at a similar period in 1908. The greatest increase was in sodium, sulphate, and chloride. The change was probably brought about by the Estrella River, which flows into the Salinas between the two sampling points. Analyses of the Estrella River by Van Winkle and Eaton show that it was higher in all mineral constituents except bicarbonate than the Salinas at Paso Robles, which might account for the increased concentration near San Miguel.

The San Antonio River at Pleyto contained in 1930 less dissolved matter, particularly calcium, bicarbonate, and sulphate, than near Bradley at a corresponding period in 1908. The discharge and concentration of the San Antonio River fluctuate so greatly, however, that no attempt should be made to predict the present character of the water from a single sample.

Six samples taken in 1930 from the Santa Ana River near Prado and two at Riverside Narrows, near Arlington, indicate that the concentration at these points was considerably greater than near Corona, a short distance away, in 1908. Because of numerous diversions for irrigation and the subsequent return of the water to the river, comparisons of analyses are not trustworthy except when made from samples collected at the same point.

Analyses of samples from other rivers studied in 1906–8—the Santa Ynez, the San Luis Rey, and the Mojave—are not comparable because of change of sampling points.

Samples from rivers not studied in 1906–8.

The remaining 86 samples were collected at 35 stations on 35 streams none of which were studied by Van Winkle and Eaton. Some of these streams are worthy of mention because of their size, location, and unusual composition.

A single sample from the Calaveras River and two from the Tule River indicate that they are more concentrated than the other tributaries of the San Joaquin River.

Piru and Sespe Creeks, the chief tributaries of the Santa Clara River, carry large and variable quantities of dissolved matter. Piru Creek was especially high in sulphate, its content ranging from 508 parts per million in May 1930 to 1508 parts per million in September. Sespe Creek, although less concentrated than Piru Creek, doubled in dissolved matter between May 20 and June 18 and again between September 20 and October 27, with a rapid lowering of concentration between June 18 and July 23. Both Piru and Sespe Creeks contain large amounts of boron, which is characteristic of both surface and ground waters in this region.[3]

Analyses of single samples from several small streams in the southern part of the State indicate that they contain chiefly calcium and bicarbonate, with relatively large amounts of sulphate. Although the discharge is ordinarily small, many of these streams are important because of diversions for irrigation, power, and other uses. They include Mill, Lytle, and Warm Creeks and the San Jacinto River, in the Santa Ana Basin; Tujunga Creek and Arroyo Seco, in the Los Angeles Basin; San Dimas Creek, in the San Gabriel Basin; and the San Diego and Santa Margarita Rivers. Dissolved solids ranged from about 120 parts per million in Mill Creek near Craftonville to 640 parts per million in the Santa Margarita River at Fall Brook.

Single analyses for several streams in the northern part of the State indicate they are higher in dissolved mineral matter than most of the rivers in the Sacramento Basin. These include Conn Creek and the Napa and Coyote Rivers, flowing into San Francisco Bay; the Pit River and Putah Creek, in the Sacramento Basin; and the Trinity River, which flows into the Klamath River, in the north Pacific slope area. The magnesium content of the Trinity River and of Conn and Putah Creeks is greater than the calcium content. This condition is frequently found in rivers along the coast. Total dissolved solids ranged from about 100 parts per million in the Trinity River at Lewiston to about 400 parts per million in Putah Creek near Winters.

Sacramento River in 1931–32.

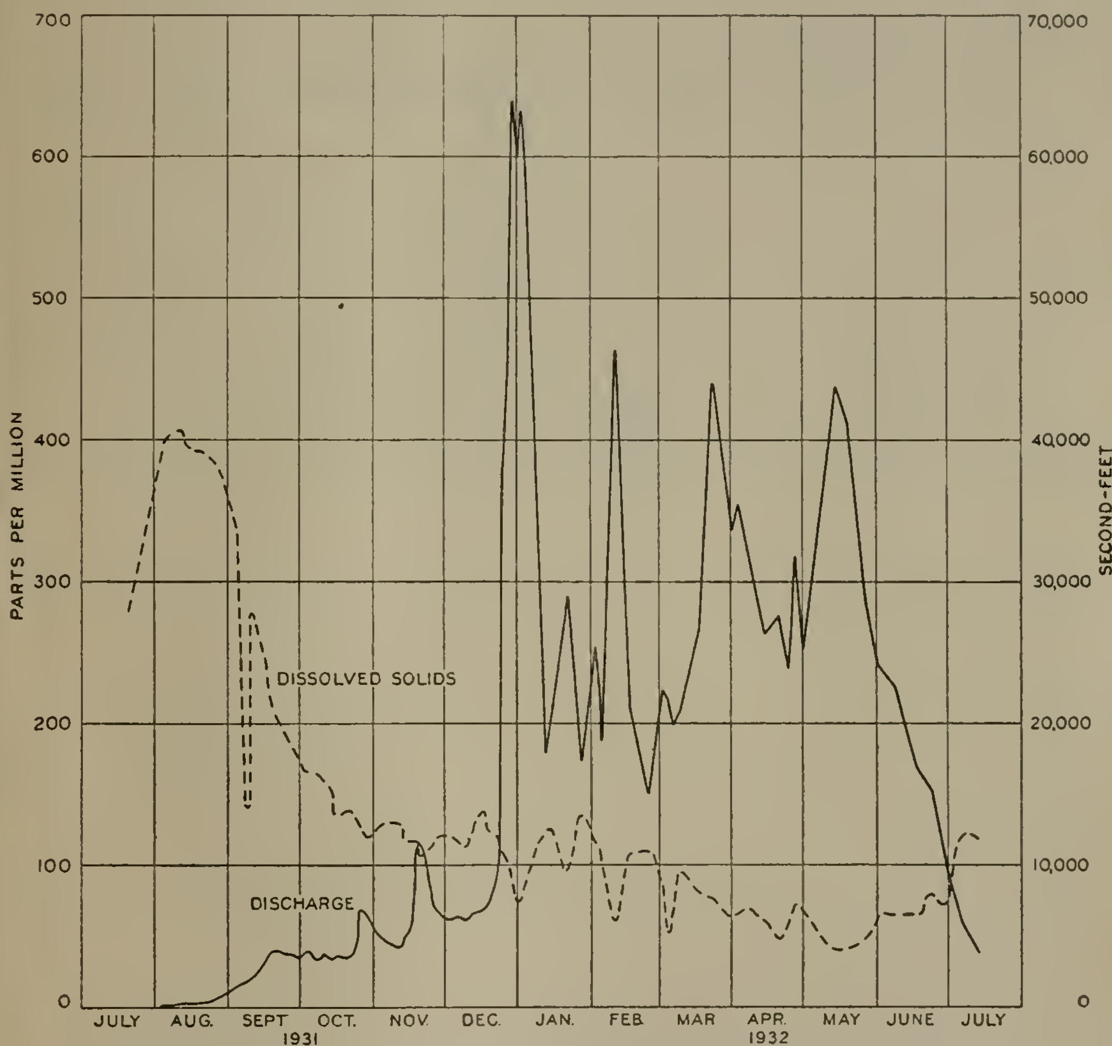
The Sacramento River at Sacramento in 1931–32 carried appreciably more dissolved mineral matter than was found by Van Winkle and Eaton in 1906 or in 1908. The average quantities for the three periods were 153, 124, and 113 parts per million, respectively. The range in concentration of the single samples in 1931–32 was greater than the range for the composite samples in either 1906 or 1908.

The quantities of dissolved solids in the samples for 1931–32 are plotted on Plate E-I, together with the mean daily discharge of the

[3] Scofield, C. S., and Wilcox, L. V., Boron in irrigation waters: U. S. Dept. Agr. Tech. Bull. 264, November 1931.

river at Sacramento. Actual discharge measurements are not made at Sacramento because of tidal influence at low stages. The plotted discharge figures have been computed[4] by using the record at Verona, 20 miles upstream, and making allowance for the measured inflow and draft between that station and Sacramento. The plotted results show that in general the concentration was lower at times of high discharge.

PLATE E–I



Dissolved solids and discharge of Sacramento River at Sacramento, California, 1931–32.

Between September 3 and 8, 1931, the concentration of dissolved solids dropped from 322 to 141 parts per million, with an increase in discharge from 1530 to 1840 second-feet. The discharge on September 10 was 2300 second-feet, but the concentration of dissolved solids increased to 284 parts per million. This was presumably caused by irrigation return water. After September 23 the concentration of dissolved solids remained below 200 parts per million until the end of the collection of samples, in July 1932. The minimum concentration found was 42 parts per million, May 18, 1932.

[4] Stafford, H. M., Sacramento-San Joaquin Water Supervisor's Report, 1931, p. 25, California Dept. Public Works, Div. Water Resources.

The chloride content changed in a general way with the total dissolved solids. After September 23, 1931, it was from 3 to 30 parts per million. The maximum chloride was found in the sample collected August 27, 1931, which had 86 parts per million. None of these results suggested any contamination from encroachment of sea water. This agrees with the figures for chloride content of the Sacramento River at Sacramento as determined by the California Department of Public Works in the salinity investigations[5] in the Sacramento-San Joaquin Delta region during 1931.

[5] Variation and control of salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay, 1931: California Dept. Public Works, Div. Water Resources, Bull. 27, pp. 365–375, 1932.

Summary.

The analyses made in 1930 indicate that the concentration of dissolved matter in certain rivers in the Sacramento, San Joaquin and Santa Ana Basins, particularly the Feather, American, Stanislaus and Santa Ana rivers, was considerably less than found by Van Winkle and Eaton, notwithstanding the fact that the discharge of these rivers was much less than in 1906–8.

The Yuba, San Gabriel, and Owens rivers and Arroyo Seco near Soledad appeared to have changed very little in concentration, but the Ventura River contained more dissolved matter than at any time in 1908.

The brief study of 1930, though it covered more streams than the earlier survey and included several stations on some of the large rivers, is wholly inadequate for estimating the average mineral content of any of the streams. The results indicate, however, that for some of the streams the older analyses may still be accepted with confidence. They also show the probability of sudden and large changes in the mineral content of some surface waters in the southern part of the State.

The complete analyses of 71 samples from the Sacramento River at Sacramento in 1931–32 show higher concentration of dissolved solids than in 1906–8 but do not indicate the salt-water encroachment.

TABLE E-2

*PARTIAL ANALYSES OF SOME SURFACE WATERS OF CALIFORNIA, 1930

(Analytical Results in Parts per Million)

Location	Date	Discharge in second-feet	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (calculated)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4) (by turbidity)	Chloride (Cl)	Nitrate (NO_3)	Borate (BO_3)	Total hardness as $CaCO_3$ (calculated)
	1930												
San Diego River near Santee	June 8	1.2	440	44	24	86	9.8	153	[a]40	150	0.15	0.1	208
San Dieguito River at Lake Hodges	June 8	----------	298	36	19	49	0	212	34	46	.10	(b)	168
San Luis Rey River at Bonsall	June 7	7	527	68	27	89	14	253	[a]74	118	.20	.2	281
Santa Margarita River at Fall Brook	June 7	5.5	634	74	23	127	14	275	[a]145	111	.20	.5	279
San Juan Creek at San Juan Capistrano	June 8	0	316	61	17	25	0	174	[a]92	26	.53	.1	222
Santa Ana River near Mentone	June 9	52	96	[c]21	----------	14	0	98	7	3.0	.10	(b)	[a]62
	July 10	43	109	[c]15	----------	16	0	106	10	4.0	.20	(b)	[a]69
Santa Ana River at Riverside Narrows near Arlington	July 10	32	446	88	19	51	0	313	[a]28	81	12	.1	298
	Nov. 12	33	471	85	19	62	0	310	[a]58	71	13	.5	290
Santa Ana River at Auburndale Bridge	July 10	40	453	76	24	54	8.9	234	[a]68	88	5.0	.4	288
Santa Ana River near Prado	June 8	70	485	76	19	75	6.9	251	[a]93	80	4.2	.3	268
	July 10	50	344	62	17	40	6.9	207	[a]39	62	4.2	.3	225
	Aug. 7	35	507	77	23	77	0	272	[a]77	107	1.0	.3	287
	Sept. 11	49	484	74	22	71	5.9	232	[a]74	105	6.4	.3	275
	Oct. 8	60	488	80	22	66	6.9	233	[a]74	103	10	.3	290
	Nov. 12	80	479	80	20	67	0	271	[a]71	88	9.0	.6	282
Mill Creek (tailrace No. 1, power house) near Craftonville	June 18	5.8	122	32	6.8	2.3	3.0	105	18	2.0	.36	(b)	108
	July 10	3.1	154	35	7.8	10	0	135	28	[c]1.5	.10	(b)	119
Warm Creek near Colton	July 10	19	262	52	10	29	0	186	25	26	22	.1	171
Lytle Creek at Fontana	June 7	27	184	50	8.5	5.6	0	173	24	3.0	1.0	(b)	160
San Jacinto River near San Jacinto	June 16	0	96	22	3.5	10	0	96	3	7.0	.10	(b)	69
Gage Canal at Tippecanoe Avenue, near San Bernardino	July 10	----------	186	43	8.3	13	0	151	28	10	3.5	(b)	142
San Gabriel River at Azusa	June 6	95	190	48	12	4.1	6.9	168	25	2.0	.10	.2	169
San Gabriel River at Paso de Bartolo	June 6	16	218	56	14	3.1	0	205	26	6.0	.57	.2	197
	July 9	45	226	54	11	15	0	212	28	6.0	.64	.1	180
	Aug. 6	24	269	68	14	10	0	244	[a]33	8.0	4.7	.3	227
	Sept. 5	14.6	260	64	13	14	0	247	[a]26	9.0	2.3	.1	213
	Oct. 6	22	266	67	14	11	5.9	234	30	8.0	4.7	.2	225
	Nov. 12	22	273	67	15	11	0	243	[a]35	9.0	5.1	.2	229
San Dimas Creek near San Dimas	June 10	2.4	335	59	26	26	9.8	271	[a]51	13	.20	.2	254
Los Angeles River, Riverside Drive and North Figueroa St., Los Angeles	June 18	----------	815	120	37	118	0	359	[a]185	150	12	.6	452
	July 8	----------	414	58	17	66	3.9	209	[a]128	32	2.3	.8	215
	Nov. 12	----------	349	71	15	30	0	236	[a]73	13	21	.2	239

Los Angeles River, Riverside Drive and Catalina St., Los Angeles	Aug. 9	....	349	52	13	55	0	194	[a]101	27	1.8	2.5	183
	Sept. 10	....	371	55	16	54	0	199	[a]114	26	2.8	1.0	203
	Oct. 6	....	550	80	24	77	0	249	[a]193	39	7.2	2.0	298
Tujunga Creek near Sunland	June 17	1.5	301	54	17	33	4.9	243	[a]53	10	.20	.6	205
Arroyo Seco near Pasadena	June 18	1.3	251	52	17	16	12	206	[a]33	8.0	.10	.4	200
Piru Creek at Piru	May 20	....	976	116	60	113	19	190	[a]508	46	.10	10	536
	June 17	....	1,283	144	75	164	0	282	[a]675	64	.10	10	668
	July 23	....	2,418	218	149	334	0	308	[a]1,418	110	.10	40	1,156
	Aug. 22	....	2,491	238	150	338	0	347	[a]1,443	113	.25	35	1,210
	Sept. 20	....	2,590	237	161	352	0	335	[a]1,508	123	.05	40	1,253
	Oct. 27	....	1,851	183	114	243	0	284	[a]1,049	91	.05	15	925
Sespe Creek at Sespe	May 20	....	616	82	32	74	0	145	[a]295	51	.20	5.0	336
	June 18	....	1,194	198	49	115	0	219	[a]653	61	.10	6.0	696
	July 23	....	521	73	21	82	8.9	167	[a]151	97	.30	15	269
	Aug. 22	....	584	72	19	113	0	196	[a]144	136	.70	20	258
	Sept. 20	....	610	74	21	116	7.9	170	[a]160	144	.10	30	271
	Oct. 27	....	1,192	174	48	151	0	206	[a]556	151	.05	15	632
Ventura River at Foster Memorial Park dam, near Ventura	May 20	....	719	127	38	59	0	279	[a]294	47	.10	1.5	473
Santa Ynez River near Lompoc	May 20	3.3	908	106	73	91	5.9	320	[a]337	99	.50	1.2	564
Sisquoc River near Sisquoc	May 20	3.7	745	104	63	46	6.9	288	[a]328	21	.05	.3	518
Cuyama River near Santa Maria	May 19	2.2	3,050	412	202	220	9.8	170	[a]1,893	150	.38	2.0	1,858
Guadalupe Creek at Guadalupe	May 7	4.2	291	48	30	12	9.8	232	44	12	([b])	.5	243
Salinas River at State highway bridge just above Nacimiento Creek, near San Miguel	May 1	....	798	85	44	135	18	304	[a]236	114	.58	1.3	393
San Antonio River at Pleyto	May 19	2.2	270	[c]36	....	3.8	15	150	[a]67	16	([b])	.1	[a]232
Arroyo Seco near Soledad	May 1	43	223	52	14	6.3	4.9	158	50	8.0	([b])	([b])	187
San Benito River just below Hernandez Valley, at Hernandez	May 2	0	589	23	121	5.3	41	531	25	26	.20	4.0	554
Coyote River near Madrone	May 7	6	327	56	27	22	9.8	236	55	23	.15	.4	251
Whitewater River Canal at Whitewater	June 16	....	248	53	14	17	3.9	197	[a]46	7.0	1.0	([b])	190
West Fork of Mojave River at Hesperia	June 10	....	143	30	7.0	14	0	130	14	9.0	.20	([b])	104
Big Rock Creek at Valyermo	June 16	....	212	48	14	9.4	3.0	193	[a]29	3.0	.36	.4	177
Owens River at Zurich, near Big Pine	Aug. 2	232	228	36	7.3	40	7.9	157	40	17	.20	.9	120
Bishop Creek at tailrace, plant No. 5, near Bishop	Aug. 2	....	25	....	....	....	0	20	4	[c]1.5	.05	([b])	[a]7.5
Rush Creek at State highway bridge near Mono Lake	Aug. 3	....	40	[c]10	....	5.5	0	36	4	3.0	.05	.1	[a]26
West Walker River near Coleville	Aug. 3	....	53	[c]11	....	10	0	53	4	2.0	.10	.2	[a]28
Kern River near Bakersfield	May 8	946	103	[c]12	....	20	11	64	14	7.0	.10	.2	[a]51
	Aug. 2	206	83	[c]14	....	22	0	66	12	7.0	.05	.2	[a]28
Tule River near Porterville	May 11	153	106	[c]13	....	9.6	0	110	3	6.0	.10	([b])	[a]81
	Aug. 1	.4	218	48	8.7	25	0	223	8	13	.10	.1	156
Kaweah River near Three Rivers	May 11	592	40	[c]10	....	8.7	12	20	1	[c]1	.05	([b])	[a]20
	Aug. 1	46	53	[c]14	....	8.3	0	49	4	4.0	.10	([b])	[a]32
Kings River at Piedra	May 12	2,330	18	[c]5	....	2.1	0	16	2	[c]1	([b])	([b])	[a]12
	Sept. 6	136	40	[c]6	....	9.8	0	28	3	8.0	.05	.1	[a]16
San Joaquin River near Friant	May 12	1,280	25	[c]3	....	7.0	0	20	1	4.0	.10	([b])	[a]8
	Sept. 6	1,050	25	[c]3	....	8.0	0	19	2	4.0	.10	([b])	[a]6.0

TABLE E-2—Continued

*PARTIAL ANALYSES OF SOME SURFACE WATERS OF CALIFORNIA, 1930

(Analytical Results in Parts per Million)

Location	Date	Discharge in second-feet	Total dissolved solids (calculated)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K) (calculated)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4) (by turbidity)	Chloride (Cl)	Nitrate (NO_3)	Borate (BO_3)	Total hardness as $CaCO_3$ (calculated)
	1930												
San Joaquin River near Mendota	July 23	....	20	[c]1	....	7.2	0	16	1	3.0	.20	(b)	[a]3
	Aug. 22	....	25	[c]3	....	8.3	0	17	2	4.0	1.1	.1	[a]4.5
	Sept. 26	....	26	[c]2	....	2.0	0	20	2	4.0	.30	(b)	[a]20
	Oct. 24	....	24	[c]2	....	2.7	0	19	2	3.0	.10	(b)	[a]16
San Joaquin River near Newman	May 14	370	135	[c]14	....	25	0	85	14	27	.88	.1	[a]69
	June 14	210	189	[c]17	....	44	3.9	110	18	40	.80	.1	[a]76
	July 18	180	153	[c]20	....	63	0	97	12	34	.67	.1	[a]63
	Aug. 22	200	139	[c]15	....	36	0	96	12	26	.58	.1	[a]51
	Sept. 26	200	146	[c]14	....	36	0	107	12	24	.87	.1	[a]57
	Oct. 24	160	461	38	18	107	0	139	[a]78	145	2.5	.3	169
San Joaquin River near Vernalis	May 16	1,390	205	[c]19	....	37	0	102	23	55	.20	.1	[a]106
	June 14	3,430	39	[c]5	....	6.9	0	35	4	[c]2	.55	.1	[a]21
	July 18	1,210	162	[c]14	....	31	0	79	20	42	.60	.1	[a]78
	Aug. 15	955	168	[c]28	....	28	0	96	10	45	1.7	.1	[a]93
	Sept. 26	1,540	179	[c]18	....	34	0	84	22	48	1.1	.1	[a]86
	Oct. 23	1,570	222	26	12	38	0	92	28	65	1.6	.2	114
Fresno River near Knowles	May 13	50	51	[c]7	....	13	0	39	2	10	.10	(b)	[a]21
	July 31	.1	144	[c]20	....	35	0	76	5	46	.20	.1	[a]57
Merced River at Exchequer	May 14	1,400	19	[c]4	....	1.9	0	19	1	[c]1	.05	(b)	[a]14
	Sept. 7	1,260	36	[c]6	....	6.0	0	32	3	3.0	.55	(b)	[a]21
Tuolumne River above La Grange Dam, near La Grange	May 7	1,780	31	[c]7	....	4.9	0	29	4	[c].5	.15	(b)	[a]18
	Sept. 7	1,840	38	[c]3	....	12	5.9	25	4	1.0	.10	(b)	[a]9
Stanislaus River near Knights Ferry	May 7	1,420	32	[c]7	....	4.6	1.0	30	3	[c].4	.10	(b)	[a]20
	Sept. 7	781	55	[c]9	....	6.5	0	55	4	2.0	.05	(b)	[a]38
Calaveras River at Jenny Lind	May 8	46	125	28	10	2.7	0	110	12	10	.20	.1	111
Mokelumne River near Mokelumne Hill	May 8	1,090	21	[c]5	....	5.1	0	13	5	2.0	(b)	(b)	[a]7.5
	Oct. 11	60	50	[c]9	....	7.8	0	38	3	9.0	.05	(b)	[a]30
Cosumnes River at Michigan Bar	May 8	370	35	[c]11	....	5.9	4.9	27	2	1.0	(b)	(b)	[a]21
	Aug. 26	1.6	61	[c]10	....	9.3	0	61	5	2.0	.20	(b)	[a]38
Sacramento River at Kennett	Aug. 29	2,820	86	[c]12	....	12	0	90	3	4.0	.45	.2	[a]56
Sacramento River near Red Bluff	July 15	3,320	95	[c]14	....	17	0	85	7	8.0	.92	.1	[a]51
	Aug. 12	3,060	90	[c]16	....	1.0	0	90	5	5.0	.15	.1	[a]84
	Sept. 16	3,400	84	[c]12	....	11	0	83	5	5.0	.10	.3	[a]57
	Oct. 14	3,490	86	[c]12	....	14	0	81	6	6.0	.10	.2	[a]51

Sacramento River at Colusa	June 10	3,470	95	[c]15	----	9.9	0	89	9	5.0	.20	.1	[a]68
	July 15	1,980	105	[c]10	----	13	0	98	10	6.0	.10	.1	[a]72
	Aug. 12	1,680	129	[c]24	----	22	3.9	102	6	18	.15	.1	[a]74
	Sept. 16	2,950	95	[c]16	----	9.3	0	85	11	5.0	.20	.2	[a]68
	Oct. 14	3,570	94	[c]14	----	12	0	91	7	5.0	.10	.2	[a]62
Sacramento River at Knights Landing	June 10	3,580	127	[c]14	----	15	0	101	18	11	.15	.2	[a]84
	July 14	1,820	145	[c]20	----	19	0	119	15	15	.48	.2	[a]93
	Aug. 11	1,540	204	[c]24	----	37	0	137	[a]25	34	.25	.3	[a]105
	Sept. 15	3,300	131	[c]16	----	18	0	101	22	10	.10	.2	[a]81
	Oct. 13	3,620	108	[c]12	----	12	0	91	14	8.0	.10	.2	[a]75
Sacramento River at Verona	June 11	8,400	67	[c]13	----	6.0	0	61	7	4.0	.10	.1	[a]50
	July 18	2,640	167	[c]24	----	23	0	118	13	31	.69	.1	[a]104
	Aug. 13	2,640	148	[c]32	----	9.0	0	132	20	6.0	.25	.2	[a]118
	Sept. 17	5,780	96	[c]12	----	13	0	81	10	9.0	.30	.1	[a]62
	Oct. 15	6,520	79	[c]14	----	11	0	78	4	5.0	.55	.1	[a]52
Sacramento River at Courtland	Aug. 7	----	214	[c]30	----	29	0	133	20	46	.77	.4	[a]132
	Sept. 18	----	170	[c]18	----	25	0	115	20	28	.87	.2	[a]100
	Oct. 16	----	105	[c]12	----	15	0	88	6	14	.42	.1	[a]66
Pit River at Bieber	Aug. 28	----	294	[c]20	----	70	3.0	263	30	16	1.2	.8	[a]123
Feather River at Oroville	May 8	6,520	44	[c]10	----	3.9	0	45	4	[c].3	.10	([b])	[a]33
	Aug. 27	1,960	63	[c]12	----	7.0	0	63	3	2.0	1.9	.1	[a]44
Feather River at Nicolaus	June 11	3,610	59	[c]7	----	7.5	0	55	7	2.0	.20	([b])	[a]39
	July 16	718	83	[c]14	----	8.5	0	79	7	4.0	1.0	([b])	[a]60
	Aug. 13	814	84	[c]20	----	7.7	4.9	74	6	3.0	.51	.1	[a]63
	Sept. 17	1,990	74	[c]10	----	7.3	0	74	6	2.0	.30	.1	[a]54
	Oct. 15	2,600	70	[c]10	----	9.4	0	69	5	3.0	.50	.1	[a]46
Yuba River at Smartsville	May 8	2,960	54	[c]8	----	10	0	36	15	[c]2	.05	([b])	[a]26
	Aug. 27	280	80	[c]18	----	9.1	0	67	14	3.0	.10	([b])	[*]54
American River at Fair Oaks	May 8	4,000	21	[c]5	----	1.7	0	22	1	[c].4	.15	([b])	[a]16
	Aug. 26	173	46	[c]9.	----	7.4	0	38	6	4.0	.20	([b])	[a]27
Putah Creek at Winters	Aug. 7	0	404	36	58	25	17	354	28	25	.56	3.0	328
Napa River near Napa	May 10	26	166	22	19	11	0	158	4	16	2.1	1.0	133
Conn Creek near St. Helena	May 10	3.2	290	36	43	3.5	4.9	275	25	10	.78	.7	266
Trinity River at Lewiston	Aug. 29	80	92	10	15	.5	0	94	6	3.0	.30	.1	86

[a] Determined by usual analytical methods.
[b] Less than 0.1 part per million.
[c] Determined by turbidity.
[*] Analyzed by S. K. Love.

TABLE E-3

*ANALYSES OF WATER FROM THE SACRAMENTO RIVER AT THE M STREET BRIDGE, SACRAMENTO, CALIFORNIA, 1931-32

(Analytical Results in Parts per Million)

Date and time of collection	Approximate stage of tide	Discharge in second-feet	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Borate (BO_3)	Total hardness as $CaCO_3$ (calculated)
1931—															
July 20— 5.40 p.m.	Low low	91	280	22	0.02	31	21	38	2.6	160	25	62	(a)	--------	164
Aug. 6— 9.45 a.m.	Low low	206	403	26	.03	40	30	63	2.1	237	43	83	(a)	--------	223
Aug. 12— 3.00 p.m.	Low low	345	406	26	.03	39	31	61	2.4	237	49	81	(a)	--------	225
Aug. 14— 8.22 a.m.	High high	369	395	26	.09	38	29	61	2.9	225	47	80	(a)	--------	214
Aug. 20— 1.26 a.m.	High high	480	394	28	.04	36	28	62	3.6	224	50	80	0.40	0.4	205
10.04 a.m.	Low low	--------	389	29	.03	35	28	61	3.0	224	48	75	.40	.4	202
Aug. 27— 8.00 a.m.	High high	737	387	27	.03	37	28	62	2.7	217	44	86	.40	.4	207
4.50 p.m.	Low low	--------	373	29	.04	34	27	55	3.0	202	40	81	.40	.4	196
Sept. 3—12.50 a.m.	High high	1,530	349	28	.03	33	25	51	3.0	194	38	72	.40	.4	185
8.25 a.m.	Low low	--------	322	27	.03	30	23	50	2.0	186	36	61	.40	.4	169
Sept. 8— 5.17 a.m.	High high	1,840	141	26	.17	16	10	16	2.6	100	12	14	.10	.2	81
Sept. 10— 6.30 a.m.	High high	2,300	271	26	.11	27	20	42	2.6	166	29	50	.25	.3	150
2.45 p.m.	Low low	--------	284	25	.11	28	21	44	3.0	173	32	54	.25	.3	156
Sept. 16—11.50 p.m.	High high	3,520	236	27	.11	23	17	34	2.9	147	22	42	.21	.2	127
Sept. 17— 9.26 a.m.	Low low	3,750	223	29	.21	22	15	31	2.6	140	25	33	.28	.2	116
Sept. 23— 3.28 p.m.	Low low	3,780	198	27	.15	20	14	27	2.4	128	19	30	.25	.2	107
Sept. 25— 7.45 a.m.	High high	3,800	188	28	.15	19	13	25	2.4	121	16	28	.25	.2	101
Sept. 30—10.17 p.m.	High high	3,490	179	28	.12	19	13	23	1.8	117	15	29	.25	.2	101
Oct. 1— 8.00 a.m.	Low low	3,670	169	28	.13	18	12	20	2.4	113	15	23	.23	.2	94
Oct. 8— 2.35 p.m.	Low low	3,420	165	28	.14	18	11	19	2.1	110	13	22	.10	.2	90
Oct. 14— 6.22 p.m.	Low low	3,450	145	28	.04	17	10	15	1.3	97	9.5	14	.14	.2	84
10.20 p.m.	High high	--------	160	26	.12	17	11	20	1.8	104	12	24	.10	.2	88
Oct. 15— 8.05 a.m.	High high	3,580	135	26	.16	15	9.6	15	1.9	97	10	14	.10	.2	77
Oct. 21— 2.02 p.m.	Low low	3,560	144	30	.04	17	10	16	.8	103	9.1	18	.12	.2	84
Oct. 29— 6.54 a.m.	Low low	6,360	120	24	.04	17	9.2	10	.9	84	11	12	.14	.2	80
Nov. 4—12.13 p.m.	Low low	4,940	131	26	.04	15	7.6	13	.8	84	12	14	.11	.2	69
5.03 p.m.	High high	--------	128	24	.03	18	8.3	14	.7	87	12	13	.15	.2	79
Nov. 11— 9.04 p.m.	High high	4,300	129	28	.04	15	8.4	14	.7	91	9.7	10	.12	.2	72
Nov. 12— 6.52 a.m.	Low low	4,580	120	24	.04	16	8.1	12	.5	87	9.5	9.0	.07	.2	73
Nov. 18— 5.00 p.m.	High high	11,300	117	20	.07	14	8.4	13	.5	71	16	10	.13	.2	69
Nov. 19— 1.00 p.m.	Low low	11,500	107	21	.06	18	6.5	9.1	.5	72	12	8.0	.12	.1	72
Nov. 25— 8.00 p.m.	High high	7,060	114	23	.05	15	7.6	9.0	.6	74	13	8.0	.12	.2	69
Nov. 26— 6.00 a.m.	Low low	7,060	120	23	.09	14	7.4	9.3	1.8	74	13	8.0	.3	.3	65
Dec. 2— 4.05 p.m.	High high	6,160	120	25	.02	14	7.9	11	1.6	79	12	11	.2	.2	67
Dec. 3—11.35 a.m.	Low low	6,350	120	24	.02	14	8.0	11	1.8	82	12	11	.15	.2	68
Dec. 9— 8.00 p.m.	High high	6,220	114	24	.02	14	7.8	10	1.7	79	11	8.0	.2	.3	67
Dec. 10— 6.00 a.m.	Low low	6,460	119	25	.02	14	8.1	9.9	1.6	82	11	9.0	.15	.3	68

Dec. 16— 3.20 p.m.	High high	6,910	139	24	.02	16	9.6	13	1.8	85	13	16	.2	.3	79
Dec. 17—11.20 a.m.	Low low	6,810	126	24	.02	14	8.2	11	1.6	84	12	11	.15	.3	69
Dec. 23— 7.00 p.m.	High high	12,100	121	20	.04	15	8.2	12	1.7	74	14	13	.3	.2	71
Dec. 24— 5.00 a.m.	Low low	24,500	112	21	.02	14	7.5	9.5	1.4	71	13	8.0	.3	.2	66
Dec. 30— 2.00 p.m.	(b)	61,000	74	14	.04	8.6	4.8	4.7	1.5	39	9.1	4.0	2.0	.1	41
Dec. 31—10.00 a.m.	(b)	60,000	74	14	.03	8.1	5.1	5.0	1.9	40	10	5.0	2.0	.1	41
1932—															
Jan. 7	(b)	36,200	114	19	.05	14	7.3	11	1.5	63	15	14	1.2	.2	65
Jan. 13	(c)	19,800	125	21	.04	15	7.9	13	1.3	72	16	16	.74	.2	70
Jan. 20	(b)	27,500	97	18	.04	12	6.3	8.3	1.4	60	12	10	.80	.1	56
Jan. 27	(c)	17,400	135	19	.06	17	8.8	16	1.8	81	20	16	.80	.2	79
Feb. 3	(c)	22,600	111	27	.04	13	6.7	11	1.4	64	13	10	.45	.1	60
Feb. 10	(b)	46,200	61	13	.04	7.5	3.6	4.1	.6	37	7.8	3.0	.60	.1	34
Feb. 16— 6.05 p.m.	(c)	21,200	109	18	.03	13	6.7	11	1.9	63	14	12	.30	.1	60
Feb. 24—10.45 a.m.	High high	15,000	110	21	.02	14	6.8	11	1.5	69	13	11	.20	.2	63
Mar. 2— 5.20 p.m.	High high	22,900	85	19	.02	12	5.0	7.5		56	8.3	5.0	.15	.2	50
Mar. 4— 1.30 p.m.	(b)	21,300	52	12	.06	6.5	2.8	5.4	.9	35	4.7	3.0	.10	.1	28
Mar. 9— 6.45 p.m.	Low low	20,600	96	20	.03	13	5.5	8.9	1.5	59	8.6	10	.10	.2	55
Mar. 17— 1.03 a.m.	(c)	27,500	82	18	.05	11	4.7	6.6	1.6	53	6.3	6.0	.15	.2	47
Mar. 24—11.00 a.m.	(b)	41,900	75	16	.05	10	4.4	6.2	2.2	49	5.8	5.0	.20	.1	43
Mar. 30— 3.20 p.m.	(b)	34,000	64	16	.06	8.6	3.4	5.3	.8	45	5.5	3.0	.20	.1	35
April 6— 3.15 p.m.	(b)	32,100	70	16	.06	9.4	4.0	6.5	1.0	46	5.7	6.0	.20	.1	40
April 14— 3.05 p.m.	(c)	26,300	60	14	.05	7.7	3.1	5.7	.8	38	5.5	4.0	.15	.1	32
April 20— 2.00 p.m.	(c)	28,300	49	12	.05	6.2	2.4	4.8	.7	28	4.7	3.0	.15	.1	25
April 27— 3.03 p.m.	(b)	30,600	72	16	.06	8.4	3.8	7.1	1.0	42	6.6	6.0	.30	.1	37
May 11— 4.30 p.m.	(b)	41,400	43	12	.06	6.0	2.5	3.8	.5	27	3.5	3.0	.40	.1	25
May 18— 3.20 p.m.	(b)	42,600	42	12	.06	5.7	2.4	3.4	.6	27	3.0	4.0	.25	.1	24
May 26— 9.45 a.m.	(b)	30,000	49	12	.06	6.1	2.8	4.3	1.0	29	4.2	5.0	.25	.1	27
June 1— 5.05 p.m.	(c)	24,000	65	16	.06	8.2	3.9	6.3	1.0	43	5.2	6.0	.20	.1	36
June 8—12.30 p.m.	(c)	22,500	65	17	.06	8.0	3.7	5.6	.9	40	4.9	7.0	.20	.1	35
June 18—10.35 a.m.	(c)	16,400	66	14	.06	8.3	4.1	7.6	.7	41	5.7	8.0	.20	.1	38
June 23— 3.30 p.m.	Low low	15,200	79	17	.06	9.6	4.9	7.8	1.3	50	6.8	9.0	.15	.1	44
June 29— 5.15 a.m.	High high	10,700	73	16	.05	8.3	4.1	7.0	1.0	42	5.8	9.0	.15	.1	38
July 7—11.15 a.m.	High high	5,460	122	19	.05	15	8.3	14	1.6	80	10	18	.20	.2	72
July 13— 1.20 p.m.	High high	3,930	119	21	.05	15	7.9	13	1.8	77	10	18	.10	.2	70

* Analyzed by S. K. Love except samples July 20 to Sept. 3 and Oct. 21 to Nov. 25, 1931, which were analyzed by C. S. Howard.
[a] Less than 0.2 parts per million.
[b] No tide.
[c] Small tidal effect.

PUBLICATIONS

DIVISION OF WATER RESOURCES

PUBLICATIONS OF THE

DIVISION OF WATER RESOURCES

DEPARTMENT OF PUBLIC WORKS

STATE OF CALIFORNIA

When the Department of Public Works was created in July, 1921, the State Water Commission was succeeded by the Division of Water Rights, and the Department of Engineering was succeeded by the Division of Engineering and Irrigation in all duties except those pertaining to State Architect. Both the Division of Water Rights and the Division of Engineering and Irrigation functioned until August, 1929, when they were consolidated to form the Division of Water Resources.

STATE WATER COMMISSION

First report, State Water Commission, March 24 to November 1, 1912.
Second Report, State Water Commission, November 1, 1912, to April 1, 1914.
*Biennial Report, State Water Commission, March 1, 1915, to December 1, 1916.
Biennial Report, State Water Commission, December 1, 1916, to September 1, 1918.
Biennial Report, State Water Commission, September 1, 1918, to September 1, 1920.

DIVISION OF WATER RIGHTS

*Bulletin No. 1—Hydrographic Investigation of San Joaquin River, 1920–1923.
*Bulletin No. 2—Kings River Investigation, Water Master's Reports, 1918–1923.
*Bulletin No. 3—Proceedings First Sacramento-San Joaquin River Problems Conference, 1924.
*Bulletin No. 4—Proceedings Second Sacramento-San Joaquin River Problems Conference, and Water Supervisors' Report, 1924.
*Bulletin No. 5—San Gabriel Investigation—Basic Data—1923–1926.
Bulletin No. 6—San Gabriel Investigation—Basic Data, 1926–1928.
Bulletin No. 7—San Gabriel Investigation—Analysis and Conclusions, 1929.
*Biennial Report, Division of Water Rights, 1920–1922.
*Biennial Report, Division of Water Rights, 1922–1924.
Biennial Report, Division of Water Rights, 1924–1926.
Biennial Report, Division of Water Rights, 1926–1928.

DEPARTMENT OF ENGINEERING

*Bulletin No. 1—Cooperative Irrigation Investigations in California, 1912–1914.
*Bulletin No. 2—Irrigation Districts in California, 1887–1915.
Bulletin No. 3—Investigations of Economic Duty of Water for Alfalfa in Sacramento Valley, California, 1915.
*Bulletin No. 4—Preliminary Report on Conservation and Control of Flood Waters in Coachella Valley, California, 1917.
*Bulletin No. 5—Report on the Utilization of Mohave River for Irrigation in Victor Valley, California, 1918.
*Bulletin No. 6—California Irrigation District Laws, 1919 (now obsolete).
Bulletin No. 7—Use of water from Kings River, California, 1918.
*Bulletin No. 8—Flood Problems of the Calaveras River, 1919.
Bulletin No. 9—Water Resources of Kern River and Adjacent Streams and Their Utilization, 1920.
*Biennial Report, Department of Engineering, 1907–1908.
*Biennial Report, Department of Engineering, 1908–1910.
*Biennial Report, Department of Engineering, 1910–1912.
*Biennial Report, Department of Engineering, 1912–1914.
*Biennial Report, Department of Engineering, 1914–1916.
*Biennial Report, Department of Engineering, 1916–1918.
*Biennial Report, Department of Engineering, 1918–1920.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

DIVISION OF WATER RESOURCES
Including Reports of the Former Division of Engineering and Irrigation

*Bulletin No. 1.—California Irrigation District Laws, 1921 (now obsolete).
*Bulletin No. 2—Formation of Irrigation Districts, Issuance of Bonds, etc., 1922.
Bulletin No. 3—Water Resources of Tulare County and Their Utilization, 1922.
Bulletin No. 4—Water Resources of California, 1923.
Bulletin No. 5—Flow in California Streams, 1923.
Bulletin No. 6—Irrigation Requirements of California Lands, 1923.
*Bulletin No. 7—California Irrigation District Laws, 1923 (now obsolete).
*Bulletin No. 8—Cost of Water to Irrigators in California, 1925.
Bulletin No. 9—Supplemental Report on Water Resources of California, 1925.
*Bulletin No. 10—California Irrigation District Laws, 1925 (now obsolete).
Bulletin No. 11—Ground Water Resources of Southern San Joaquin Valley, 1927.
Bulletin No. 12—Summary Report on the Water Resources of California and a Coordinated Plan for Their Development, 1927.
Bulletin No. 13—The Development of the Upper Sacramento River, containing U. S. R. S. Cooperative Report on Iron Canyon Project, 1927.
Bulletin No. 14—The Control of Floods by Reservoirs, 1928.
*Bulletin No. 18—California Irrigation District Laws, 1927 (now obsolete).
*Bulletin No. 18—California Irrigation District Laws, 1929, Revision (now obsolete).
Bulletin No. 18-B—California Irrigation District Laws, 1931, Revision.
Bulletin No. 19—Santa Ana Investigation, Flood Control and Conservation (with packet of maps), 1928.
Bulletin No. 20—Kennett Reservoir Development, an Anaylsis of Methods and Extent of Financing by Electric Power Revenue, 1929.
Bulletin No. 21—Irrigation Districts in California, 1929.
Bulletin No. 21-A—Report on Irrigation Districts in California for the year 1929.
Bulletin No. 21-B—Report on Irrigation Districts in California for the year 1930.
Bulletin No. 21-C—Report on Irrigation Districts in California for the year 1931. (Mimeographed.)
Bulletin No. 21-D—Report on Irrigation Districts in California for the year 1932. (Mimeographed.)
Bulletin No. 22—Report on Salt Water Barrier (two volumes), 1929.
Bulletin No. 23—Report of Sacramento-San Joaquin Water Supervisor, 1924–1928.
Bulletin No. 24—A Proposed Major Development on American River, 1929.
Bulletin No. 25—Report to Legislature of 1931 on State Water Plan, 1930.
Bulletin No. 26—Sacramento River Basin, 1931.
Bulletin No. 27—Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay, 1931.
Bulletin No. 28—Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, 1931.
Bulletin No. 28A—Industrial Survey of Upper San Francisco Bay Area, 1930.
Bulletin No. 29—San Joaquin River Basin, 1931.
Bulletin No. 31—Santa Ana River Basin, 1930.
Bulletin No. 32.—South Coastal Basin, a Cooperative Symposium, 1930.
Bulletin No. 33—Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain, 1930.
Bulletin No. 34—Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley, 1930.
Bulletin No. 35—Permissible Economic Rate of Irrigation Development in California, 1930.
Bulletin No. 36—Cost of Irrigation Water in California, 1930.
Bulletin No. 37—Financial and General Data Pertaining to Irrigation, Reclamation and Other Public Districts in California, 1930.
Bulletin No. 38—Report of Kings River Water Master for the Period 1918–1930.
Bulletin No. 39—South Coastal Basin Investigation, Records of Ground Water Levels at Wells, 1932.
Bulletin No. 40—South Coastal Basin Investigation, Quality of Irrigation Waters, 1933.
Bulletin No. 41—Pit River Investigation, 1933.
Bulletin No. 42—Santa Clara Investigation, 1933.

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

Bulletin No. 43—Value and Cost of Water for Irrigation in Coastal Plain of Southern California, 1933.

Bulletin No. 44—Water Losses Under Natural Conditions from Wet Areas in Southern California, 1933.

Biennial Report, Division of Engineering and Irrigation, 1920–1922.

Biennial Report, Division of Engineering and Irrigation, 1922–1924.

Biennial Report, Division of Engineering and Irrigation, 1924–1926.

Biennial Report, Division of Engineering and Irrigation, 1926–1928.

PAMPHLETS

Act Governing Supervision of Dams in California, with Revised Rules and Regulations, 1933.

Water Commission Act with Amendments Thereto, 1933.

Rules, Regulations and Information Pertaining to Appropriation of Water in California, 1933.

Rules and Regulations Governing the Determination of Rights to Use of Water in Accordance with the Water Commission Act, 1925.

Tables of Discharge for Parshall Measuring Flumes, 1928.

General Plans, Specifications and Bills of Material for Six and Nine Inch Parshall Measuring Flumes, 1930.

COOPERATIVE AND MISCELLANEOUS REPORTS

*Report of the Conservation Commission of California, 1912.

*Irrigation Resources of California and Their Utilization (Bul. 254, Office of Exp. U. S. D. A.) 1913.

*Report, State Water Problems Conference, November 25, 1916.

*Report on Pit River Basin, April, 1915.

*Report on Lower Pit River Project, July, 1915.

*Report on Iron Canyon Project, 1914.

*Report on Iron Canyon Project, California, May, 1920.

*Sacramento Flood Control Project (Revised Plans), 1925.

Report of Commission Appointed to Investigate Causes Leading to the Failure of St. Francis Dam, 1928.

Report of the California Joint Federal-State Water Resources Commission, 1930.

Conclusions and Recommendations of the Report of the California Irrigation and Reclamation Financing and Refinancing Commission, 1930.

*Report of California Water Resources Commission to the Governor of California on State Water Plan, 1932.

*Booklet of Information on California and the State Water Plan prepared for United States House of Representatives' Subcommittee on Appropriations, 1931.

*Bulletin on Great Central Valley Project of State Water Plan of California Prepared for United States Senate Committee on Irrigation and Reclamation, 1932.

---

* Reports and Bulletins out of print. These may be borrowed by your local library from the California State Library at Sacramento, California.

o

80997 1-34 1M